MODERN ARMAMENTS

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MODERN ARMAMENTS

by

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FOREWORD

WAR, WE ARE TOLD may be good, bad, righteous, criminal, or any number of other things which depend upon the point of view adopted and our distance from the scene of battle. But it cannot be uninteresting or boring when it happens outside our front door. As it is now possible to fly from London to Australia in about three days there is never enough distance to lend enchantment to any warlike view. The main reason why romantic murders in Tibet are less exciting to the public than those in Piccadilly is that the fare to Tibet is costly. In the case of war money is always available so that even this difficulty of expense does not apply.

Fighting between nations is rather like the semi-gambling competitions which are popular among coupon sportsmen. That is to say, in one respect. For the controllers usually make their fortunes while the rest only hope to do so. And the stakes are enormous. Force, life and death are the greatest gambles of all. It is natural that we should be thrilled and that we should save the greatest honours for those who put down the greatest stake. Always remembering, I hope, that honour and money are not essentially interchangeable.

If a building is put up and we hear that it costs one million pounds we are interested. In Great Britain we have spent about £700,000,000 in one year on war; perhaps a great deal more. A sum which makes all other purchases look petty. Yet there are very few who know anything of the goods they are buying. We read of bombs, shells, torpedoes or gas, we talk of weapons firing hundreds of bullets in a minute, and still we have not had time to find out the answer to the old question: "How does it work?"

Nor can we be sure that all this money will accomplish its object, or that it will bring us back to a world of interest, instead of contracts, commissions and patriotic profits. We used to pay others to fight, but now we both pay and fight at the instance—of parties who are not alway disinterested or who may profit largely as the result of "coming to their country's aid". What makes all this so peculiar is that war does not pay the masses who give their money and their lives. It is only useful to very few. At the end of any war, for reasons no doubt of that strange thing called high finance by which important munitions are supplied to countries against which one is arming, it may be essential that one's enemies should not be ruined lest the balance of paper money be destroyed.

Many years ago when money and goods were more comparable, war might have been useful; for men marched to the opposing castle in rags, stole the contents of the fortress, complete with gold, clothes and women. They then marched home in comfort, or even in luxury. Nowadays the General-Politician has unhappiness and ruin to face him, for he dare not

burgle the castle and the painful result is that he marches home, still in rags and without the exciting appurtenances which have been already enumerated.

I have no wish to be hard. It is sufficient to explain that logic does not enter into commercial warfare. A country can, and does, beg combatants to cease their killings; while supplying munitions, up to more than half of the total requirements, to the same aggressors upon whom they urge the benefits of gentle peace. This is either funny or unspeakably wrong.

It may be that in no other walk of life has science so changed the nature of employment as in the case of the army. Years ago the Stage "mother" would burst into tears as she proclaimed that the family downfall was complete, by the words: "Bill 'as gorn for a sodjer!" To-day Bill interrupts a course on astrophysics that he may supplement his knowledge with matters of ballistics, Bren guns or balloons; and as it is all these instruments which he must thank for his improved status with vastly increased pay, even science should come into its own. Not that this matter of finance is at all exaggerated for when soldiers really have to fight it would be impossible to pay them adequately. I believe that in this sentence will be found the solution to most military problems.

Even on the much discussed "social plane", vast changes have occurred. Although it is still very difficult to be an officer and painfully simple to "join up" there is no longer the distinction between an automatic gentleman or the last refuge of a poor man. Science has changed both positions to one of pride. Soldiers and sailors need skill, knowledge and technical training

in every branch of their service. Air mechanics are as vital as any staff.

It was all so easy, so respectable, when we had but to hire some unsuspicious individual with a strong arm and a "trusty sword". The same sword of which one hears that those who live by it shall die in the same way. Nowadays, fighting is rather more complicated. We need chemists, bacteriologists, physicists, engineers, architects, electricians and even artists to indulge their natural propensities for camouflage. We must have the assistance of radio and printing to support our morale or our religious philosophy. We must, in short, be certain that we are fighting for the right without there being the slightest suspicion that "might" is the word we sought.

Nature, I confess, often conceals the love which led to evolution and makes it very clear that physical fighting is one of her methods. Trees fight, so do dogs, so do men. We still have the form of savages visible upon our hairy bodies and in certain childlike sports. We do not choose policemen, without whom the law would be a bad joke, for their chess-playing ability. We use force; and each man, woman or child fights for his own goods in exactly the same way as his ancestors fought half a million years ago. But he has better weapons.

CHAPTER I

THE NATURE OF WAR

THIS BOOK is intended to outline the scientific principles on which modern weapons are based and to indicate something of their development or probable use in the event of a future war. It is neither a treatise on tactics nor a military drill manual, although tactics and drill must be founded on the development of every weapon of offence and defence. It is not a history of warfare, although inevitably to-day's weapons have evolved from those of yesterday and to-morrow's will evolve from the weapons of to-day. It is a popular book, in the sense that it is intended for non-technical readers. So, possibly, highly-qualified engineers, chemists and military experts will forgive me if, occasionally, I appear to have departed from the strictest accuracy, in a search for simplicity.

The introduction of what may be called scientific weapons of war has completely altered the attitude of the public towards war itself, the favourite occupation of Man for thousands of years. There is no longer any question of Britain being involved in a war which can only concern the average person as a headline in the newspapers. We now realize very fully

that if we enter any war, we are all, from the youngest baby to the oldest inhabitant, a combatant for twenty-four hours a day. It is even being said, although this is an exaggeration, that soldiers and sailors will be safer than the civilian. If this book had been written fifty years ago it would, no doubt, have given great comfort to those who read it, for it would have assured them that our army and navy could keep all comers from our shores and that in the event of war we could continue to live quietly in town or country with a minimum of discomfort, untroubled except by the distant boom of guns. That idea of war is no longer possible for any country.

Perhaps I should make my personal position clear. In so far as personal opinions and not facts are recorded, they may lead to my being called bloodthirsty, optimistic, pessimistic, cynical or indifferent, according to the views of the reader. The fact that I have written on modern methods of destruction does not imply that I approve of them. On the contrary I know only too well to what better purposes the vast sums being expended on armaments could be put.

With one-hundredth the sum we are spending on preparing to destroy, we might find a cure for cancer and save thousands of lives a year. With a tenth of the sum, we could build roads which would avoid an annual casualty-list that reads like that of a major battle. But the fact is that we have decided—and when I say *we* I do not mean simply Britain, but all the nations of the world—to spend the money otherwise. This is not just a temporary phase as some would suggest, but a permanent policy. At no time in the

world's history has the amount expended by governments on scientific research, for the purpose of saving life or of reducing pain, equalled that poured out on equipment for destruction: it has always been easier to raise money for guns than hospitals. My view is that having embarked on this policy, or rather having never departed from it since the evolution of Man, it is important that we should understand something of the weapons of offence and defence of which we may have practical experience. I am a pacifist in the sense that I do not believe in fighting as the only honest way of settling disputes. But if the final judgment must be force, then I think it is sensible to apply science to that end. In the same way, I do not believe in capital punishment, but if I cannot have my way with an altered law, then I think it best to use science to make death as quick as possible.

I am reminded of a story of Bismarck and a certain scientist. They quarrelled, and Bismarck issued a challenge to a duel. The scientist accepted—the alternative according to the code was dishonour. Bismarck gave him choice of weapons. The scientist sent round two sandwiches, explaining that one contained the bacilli of a painful, always fatal, disease, while the other was perfectly harmless. He offered Bismarck his choice, saying: "These are my weapons and this is as sensible a way of settling the dispute as pistols or swords." Bismarck, of course, refused both sandwiches and the matter was laughed away, but I have always thought the scientist showed perfect logic. I can only hope that he, very sensibly, had tucked away an antidote to the deadly disease so that if he had

been "unlucky" his superior intelligence would still not have been sacrificed to brute force.

The introduction of science and particularly explosives to war, had an effect which is often overlooked. It puts the "little man" on the same footing as the "he-man". A child can squeeze the trigger of a revolver and the bullet kills the strong man as effectively as the weakling. Since brains and brawn rarely go together, the evolution of Man as a thinking animal has been accomplished by sacrificing his strength. This has meant that in the long run victory has gone to the more intelligent peoples. Admittedly a broad statement, but it will be found, I am sure, to be true in the end. Modern war calls for much more than physical strength. The qualities of intelligence, or morale are much more likely to be found in a free country where men are allowed to develop their minds than in any country of physical and intellectual slavery.

I believe that excuses are no longer fashionable at the beginning of books, but I will be unfashionable and excuse myself on the grounds that war has been the one great topic uppermost in the minds of the peoples of the world for the last three years. Or perhaps I should say that with love, it is a topic that is always in people's minds. There is a tendency to consider that our normal state is peace, and that war is an incidental, an abnormality occurring between intervals of peace. But what are the facts? It has been calculated that in the last 3,400 years, the period of which we have reasonably accurate historical accounts, there has been war in the civilized parts of the world for 3,140 years and peace for only 260 years!

This suggests that from the dawn of civilization war has been the normal condition of mankind, and that it is the periods of peace which have been the incidental interludes. Fighting is, of course, the normal characteristic of the animal world of which we are a part. We know that the simplest living cells destroy others in their struggle for existence and that from the climbing plant that destroys its neighbour in an endeavour to secure more light, to the wolf that establishes its position as leader of a pack by tearing out the throat of any challenger, life is a struggle. The survival of the fittest does not mean the survival of the strongest or the best fighter; but in the course of evolution the development of protective and offensive weapons, varying from a tough hide to sharp teeth, has been part of the survival of the fittest.

Man was created when it was decided to sacrifice some of these natural weapons to thought. So long as the body was merely a fighting machine and the brain concerned simply with getting food or destroying enemies, there was little possibility of development. We cannot here go into the origins of Man, but if I may sum up one aspect of the matter quite non-technically, what has happened is that men living near each other said: "Look here, it is foolish to waste our energy fighting each other when there are so many better things to do. Let's agree to live together and observe certain rules. If you have a dispute with me, I won't hit you over the head, but we will go before a jury of our fellow creatures who will settle the case and we will both agree to abide by their

decision." Man, released from the necessity of being constantly on his guard against attack and having to fight even for the mere right to live, began to develop other arts than war.

Unfortunately, what men could sometimes agree about individually in small communities, they could not agree in large groups or nations. Individual war gave place to the tribal war which in turn led on to war between nations. When we remember the millions of years it took to establish even elementary ideas of law and compare them with the few centuries that have elapsed since tribal war became national war, it is not surprising, perhaps, that the ideal of international justice arranged on the same basis as national justice is still so far from attainment.

Evolution is a much slower process than the layman is apt to imagine, and a thousand years is an absurdly short time in which to bring about any fundamental change in human thought or character. If scientists were dealing with animals instead of human beings they would, no doubt, cross various strains selected for their pacific characteristics and produce a race of men to whom war would be instinctively revolting. But we have not yet tried scientific experiments in the improvement of the race and, in any case, it is very possible that in this process of eliminating combativeness we should lose certain other most desirable traits in human nature. Such progress as has been made towards the desire to eliminate war can be attributed to an increase of reasoning. For war to a reasonable man might seem generally impossible. It solves no problems. The old idea that it was the ultimate

court of appeal is now rejected, every war to end war having proved merely to be the cause of yet another war.

Why then, it may be asked, do we continue to have wars and to prepare for another Greater War? Many answers are given to a question which is really outside the scope of this book. Wars may be due to the scheming of international armament kings, to the greed of particular rulers, or to one of a hundred other causes. But ultimately they are due to the fact than Man is still a jealous, competitive and combative animal. All kinds of disputes and incidents may be the immediate cause of a war; men and women may be aroused by evil-minded financiers or foolish statecraft. But, ultimately, the responsibility is theirs and they get war simply because they want it. For it is certain that if the peoples of the world did not like fighting, they just would not fight. I doubt if bad kings, finance, or even man's inequality could make the public eat sand. Not even by propaganda, religion or advertising. Because the public does not like sand. Nor can the love of war be instilled although such a natural tendency is not very difficult to develop.

Perhaps I have dealt at undue length with the cause and responsibility of war; but I am anxious to make it clear that war is not due, as is so often stated, to modern science. Many people have put forward the viewpoint that if there had been no research and invention, there would be no war; forgetting, apparently, that when men have been able to find nothing else, they have fought with their bare fists. The idea

that inventors or discoverers of gunpowder, high explosive or poison gas are responsible for war is ridiculous. There used to be, I believe, a French general who whenever he captured an enemy carrying one of the crude muskets of the day, had him put to death on the grounds that it was not sporting. Various conferences have tried to "outlaw" certain weapons, as if it were possible to legislate against war when war itself is a negation of the whole idea of legislation. There were people who professed to be surprised when the Germans, in defiance of certain international laws, introduced poison gas in the last war. It should have been no cause for surprise. Once you have said "To blazes with all reason and order," which is what war amounts to, it is quite logical to use the most effective weapons that can be discovered. And, other things apart, it is not surprising that scientists have helped a just cause by evolving weapons. We should not lose sight of the fact, incidentally, that both sides in every war have always considered their cause divinely just.

What, in fact, science has done is to make war not an occupation for a small percentage of the population of the world, but something which affects everyone. Moreover, in these days of specialized commerce, it affects not only the actual nations engaged in warfare, but also every other. Neutrality merely consists in obeying a set of arbitrary rules, and there is in truth no such thing as real neutrality. The next war would have to be a world war in the proper sense of the phrase, for the so-called neutral nations must help one side or the other by trading with them. More-

over, the long range of modern weapons means that distance is no safeguard. Every country has been brought within striking distance of some other country which might in certain circumstances resort to arms.

The charge against science is sometimes narrowed down to one that it has made possible the most horrible of all kinds of warfare—chemical warfare—that it has made war much more savage and death more horrible. These statements will not bear close examination. Chemical warfare is no more barbarous than any other kind—indeed, not until we get rid of the idea that killing a man in one way is excellent and killing him in another, or with a larger gun, is definitely barbarous, are we likely to abandon war altogether. War is not sport although one may train for the other. I doubt whether, to civilized man, the slow torture of the savage to his own kind is any more painful than hanging, which we regard as the quickest of all deaths. As regards chemical warfare, and notably gas, statistics which I quote in the chapter devoted to this subject prove that if the object of a weapon is to disable the maximum number of the enemy temporarily, with a minimum of deaths, gas is the most humane weapon yet invented. The percentage of deaths is much smaller than with explosives or cold steel.

The idea that scientific inventions have made war more horrible is purely sentimental. It has resulted in far heavier casualties in a given period—more men die in a single modern battle than were killed in the whole of the Crimean War. But the difference is simply

one of time. Modern weapons may kill more quickly, but in the end the same numbers are dead whether the weapon is the spear or high explosive. A "Hundred Years' War" is inconceivable to-day because modern weapons are so expensive and strike so quickly that no nation could continue fighting continuously for this period. But the idea that every new weapon makes war more terrible is not supported by the facts. Complete extermination of a tribe was not uncommon when the aggressors used only swords and not machine guns.

The same people, who vaguely, I think, believe that the destruction of all scientists would bring eternal peace, assert that science is responsible for having brought war into our homes. That again is untrue. I doubt whether the damage to "open towns" by modern aerial bombardment is any greater than that which used to be done when it was the accepted practice to set fire to a captured town, slaughter the male civilians and children and rape the women. Modern explosives merely do it more quickly and aeroplanes present more convenient methods of transport. One day, aeroplanes will help by travel and the effects of intermarriage, to bring peace. The English do not fight Scots now that knowledge has taught us that it would be a waste of time.

The fact is that the more things have changed, the more they have remained the same. War has always been a bludgeoning of reason. It has always meant killing. No weapons have made, or could make, it worse or better. If I invented a rifle firing a humane cartridge which anæsthetized the victim for a few

hours and the nations agreed to use no other weapon, this would not make war much better, because it would still be the unscientific assertion of force over reason.

Against the number of lives destroyed by weapons resulting from scientific inventions and discoveries, we have the number saved by their aid. Antiseptics, immunization from typhus and cholera have probably saved as many lives as high explosive has destroyed. If you say how much better to save the lives without destroying the others, I heartily agree, but the use to which inventions are put depends upon the sum of human thought at the time and not upon the scientist. War is never glorious; its responsibility can never be shirked by the inhabitants as a whole.

The Great War was the first in which more men were killed by enemy action than by disease. Here are some figures for three recent wars.

	Killed in Battle	*Died from Disease*
Crimea ...	4,600 (British)	17,500 (British)
	20,000 (French)	75,000 (French)
American Civil War ...	182,000	364,000
Boer War ...	6,500	11,300

It may sound rather contradictory to speak of science saving lives in battle, but this is exactly what it does. It may be argued that the greatest number of casualties of war do not occur on the battlefield, that the physical and moral effects of war on civilians is far greater in a modern war. I am inclined to agree. We have only

to recall the revolution, famine and disease which occurred in Europe after the Great War to realize the truth of this suggestion. I should say that at least an equal number of people were killed in this way as lost their lives on the battlefields. But here again, science has improved rather than worsened the lot of the non-combatant. The famines and diseases of Europe would have been more deadly but for comparatively scientific research into dietary principles. It is recorded that during the Thirty Years' War, the population of Europe was decimated to the extent of 17,000,000, of whom only 500,000 died as the result of wounds. If the relative population of Europe is born in mind, it will be seen that in spite of modern scientific weapons, the chances of the civilian surviving are increased by science.

The greatest change that has taken place in war as the result of the introduction of what may be called "scientific weapons" is that it has become the struggle not of one army against another, but of one nation against another. Whether they like it or not, every single person on both sides is engaged in the war. The distinction between combatants and non-combatants, always rather artificial, has disappeared. We complained during the last war because women and children were bombed—women who were engaged in making munitions with which to destroy their enemies, and children who were perhaps knitting socks for the soldiers or who, in any case, would have grown up to become soldiers. The bombing of women and children is a perfectly logical development of war. I do not say I agree with it, but it was inevitable once war de-

veloped from the pastime of generals into a military, and above all an economic, struggle.

A modern war is won at least as much in the factories as in the field. Quite apart from the production of weapons, it is in the factories that the money is obtained for continuing the fight. It is not accepted, I think, that it is at a nation's industrial strength that future war-makers will strike. It was by blockading France that we defeated Napoleon and by blockading Germany that we tried to defeat her. Where the blockade is impossible, nations will obviously attempt to get the same effect by striking at sources of supply.

There is no industry which does not contribute something to a country's armed forces, directly or indirectly. Indeed war is becoming an industry and we now require three or four "soldier-workmen" behind the lines for every one actually engaged in fighting. The various classes in which apprentices are trained in the army give some idea of the industrialization of the army—a boy may become a soldier as armourer, artificer, blacksmith, electrician, fitter, instrument mechanic, mason, painter and decorator, surveyor, tinsmith, turner and wheeler. The list does not mention any actual fighting! With the navy and air force technical or scientific training is even more important. I believe that for every pilot thirty men are required "behind the lines".

Recognizing that war has become an industry, the importance of science has greatly increased. In a speech not long ago, Lord Chatfield said: "By the energy and devotion of our scientific staffs we have harnessed science in such a manner that the risks and

anxieties of ten or twenty years ago are, in many respects, no longer of the same degree. . . ."

I hope in this book to give some idea of this scientific work that has been, and is being, done; although it is obvious that details of recent weapons cannot now be revealed.

CHAPTER II

EXPLOSIVES

EXPLOSIVES ARE the basic weapon with which modern war is fought. Without them, war would be largely a matter of hand-to-hand combat. The advantage of striking the enemy at a distance was appreciated, of course, long before the invention of gunpowder, the bow, the crossbow and the javelin were the "small arms" of pre-explosive days while the catapult provided a very clumsy form of artillery for siege operations. These weapons utilized no force other than by the strength of the people who employed them. They merely stored up energy, accumulating it slowly, ready for its sudden release. The bow in itself contains no energy. The force that shoots an arrow is obtained from the muscular movements of the archer when he bends the bow, the wood storing up the energy put into it until it is required.

An explosive provides its own energy, requiring no muscular strength, except the trifling amount of mechanical movement needed for ignition. The great change explosives brought to warfare was not only the increased power available, but also the levelling of man's strength. They marked the end of the heavily

armoured knight on horseback. No longer was the giant at a great advantage over the smaller man. A sick man on his bed, provided he had sufficient strength to squeeze a trigger, could destroy a healthy man of twice his size.

What is an explosive? Briefly it is a mixture of compounds which under certain circumstances undergoes rapid chemical changes with the production of gases and heat. Every explosion may really be divided into two parts, non-technically, there is first the rapid production of a large volume of gas, and then the further expansion of this gas by the heat of the chemical action involved. The gases are of many different kinds depending on the chemicals of the explosion but, as one would expect, carbon dioxide is generally the largest by volume. Explosion must not, in this case, be confused with burning, although in many cases a hot flame is produced. Burning usually requires the presence of oxygen gas and is a relatively slow process. Many explosives burn, but can do so quite quietly. Gunpowder, for instance, when it is ignited in an unrestricted space with air, simply sizzles gently or flashes, instead of exploding violently. The difference between a fuse and the bomb which it ignites is not so much one of the contents as of the method of "packing".

The effect of the sudden generation of gases many times the volume of the original substances and of the heating of those gases, is the production of great pressure. Actually the gases are generated and heated almost simultaneously. The pressure may be used in different ways, to propel a bullet down the barrel of

a rifle or to burst the steel covering of a shell into pieces. In the motor-car we use an explosion to push the piston down and turn the crank-shaft. In this case the explosive is a mixture of gases and the explosion takes place comparatively slowly. There is no theoretical reason why gunpowder, cordite or any other explosive should not be used as fuel instead of petrol vapour and air, except the difficulty of control with the more rapid spread of the explosion.

Although the explosion in the cylinder of an internal combustion engine seems to take place instantaneously, in practice, it takes an appreciable time. The flame from the spark travels down the cylinder and the expanding gases push the piston in their effort to "escape". Petrol and air not only provide an explosive which can be conveniently controlled, but their flame travels comparatively slowly when ignited. They are not less violent explosives than many used in war, indeed, weight for weight, they produce greater pressure than nitro-glycerine.

Explosives can be classified in various ways in accordance with their utility, their chemical constituents, or speed. The propagation speed of an explosive may vary from only a few yards a second to many thousands of yards a second. What we call "high" explosives, are those having a great "speed". If a cartridge of nitro-glycerine five miles long were fired at one end, less than a second would be required for the explosion to travel to the other end. Gunpowder and cordite are much slower. It will be readily appreciated that high explosive cannot be used for normal propelling, because the sudden expansion

would burst the gun containing them. An explosive with a slower speed is required for this purpose, the action of pushing a bullet or shell down the barrel being roughly the same as that of pushing a piston down a cylinder. But the shell itself may be filled with high explosive, for the effect required when it strikes its objective is shattering rather than propelling. Aerial bombs are filled with high explosive because they receive their propelling motion from the force of gravity.

The first explosive invented was gunpowder, a mixture of charcoal, sulphur and saltpetre or potassium nitrate. It is interesting to note that its invention by Friar Bacon was due to his discovery of the method of preparing pure substances by crystallization. He was able to prepare pure nitre. This was in the fourteenth century and it is rather astonishing that gunpowder remained the one explosive for four hundred years, the only change taking place being small variations in the composition of the powder.

The normal composition of gunpowder is about four parts of nitre to three each of sulphur and charcoal. The chemical actions which take place when this is ignited in a confined space are numerous and result in the production of about 200 times the volume of some half-dozen gases of which carbon dioxide, nitrogen, and carbon monoxide are the most important. This increase in volume is made vastly greater by expansion to a high temperature. The characteristic smell of exploded powder is due to the presence of sulphuretted hydrogen. Nitre has a large amount of oxygen lightly held in combination with potassium


EHX 118

and nitrogen. Charcoal and sulphur are substances which eagerly combine with oxygen when heated.

The basis of the chemical action, which we call an explosion because of its speed or violence, is the taking up of the oxygen by the charcoal and sulphur. The small variations in the composition of gunpowder made during the four centuries when it was the only available explosive, were designed to slow down its speed for blasting operations. This was done by using more sulphur and less charcoal; its improvement for military purposes being effected by increasing the amount of nitre and substituting a cellulose composition for charcoal. This produced the so-called "brown powder".

Although gunpowder revolutionized war it was not a very powerful explosive, and it suffered from various disadvantages. First of all it was bulky in comparison with the force produced. To fire a modern big gun with gunpowder and propel a shell to a distance of twelve miles would require the muzzle filled completely with the powder. Then it had to be ignited with a flame, originally a match and later a flint-lock or by percussion. Whereas it was fairly stable in the sense that it would stand a good deal of knocking about without exploding, any spark or flame was a constant source of danger and accidental explosions were frequent. Further, the explosion resulted in a considerable amount of solid substances being produced which were finely divided and expelled by the force of the explosion, producing a smoke that enveloped the gunners.

For centuries battles were fought through smoke-

screens which made it difficult to tell friend from foe. In open country every shot, by the puff of smoke produced, instantly revealed the hiding-place of any concealed sniper. The range at which battles were fought was not greatly increased for, owing to the limited propelling force of gunpowder, bullets were not effective much beyond a hundred yards. This limited force also meant that the bullet at anything far beyond point-blank range took a very curved course and dropped onto the target rather than struck it directly.

The story of modern explosives began with the discovery of gun-cotton and nitro-glycerine, followed by the whole series of substances which exploded violently when heated. Later came another series of chemicals which exploded when detonated, that is to say, subjected to sudden sharp force.

The propellants used to-day are mostly dependent upon nitro-cellulose and nitro-glycerine for their explosive properties. The proportion of nitro-cellulose, or gun-cotton, as it is often called, and of other substances incorporated, depends upon the use to which the propellant is to be put. Gun-cotton is prepared by the action of nitric acid on purified cellulose of which cotton and wood pulp are the commonest. The exact nature of the substances produced depends upon the time and temperature of the reaction and it can easily be controlled. For explosives, a nitro-cellulose containing a high percentage of nitrogen is required. Nitro-celluloses containing lower percentages of nitrogen are used for the production of celluloid, photographic films and artificial silk. The close relation between explosives and other important industries will

therefore be at once realized. Had it not been for the Haber and allied processes it is doubtful if the nitrate supply would have been able to maintain the German explosive output during the years of the last war.

These first attempts to use gun-cotton for military purposes gave rise to so many accidents that it was thought it would have to be abandoned. But most accidents were eventually traced to chemical changes taking place in the explosive during storage, as a result of impurities. When a method of washing out these impurities during manufacture was evolved, the explosive became both safe and stable. It is also rendered less likely to cut or injure its enclosing chambers while burning.

So-called smokeless powder is made by mixing the nitro-cellulose with a volatile chemical such as acetone, working the mass produced so as to get it even and non-porous, and then cutting it into the desired shape, strips or strings. The acetone afterwards evaporates, leaving the nitro-cellulose.

Nitro-glycerine is prepared by the treatment of glycerine with nitric and sulphuric acids, the temperature being very carefully regulated. Because it is so sensitive, nitro-glycerine cannot be used, at least for military explosives, in its pure form. The oily liquid is the "soup" used by safe-breakers and the number of accidents in which burglars have destroyed themselves as well as the safe show that this is a very difficult explosive to handle. To make it safe, it is mixed with wood-flour or some other similar solid substance. This produces the familiar sticks of dynamite. In cordite, nitro-glycerine is mixed with nitro-

cellulose and vaseline or soft paraffin is used as a stabilizer.

The great disadvantage of the first cordites were the excessive wear they placed on gun-barrels by the high temperature they produced and by erosion of the metal. This meant that only a limited number of shells could be fired before the barrel was so worn that it did not fire a shell accurately and had to be re-lined. The difficulty was overcome at the beginning of the century by the production of a cordite containing a smaller amount of nitro-glycerine. M.D. cordite contains 65 per cent nitro-cellulose and 38 per cent of nitro-glycerine, with 5 per cent of vaseline as a stabilizer. The first cordite, Mark I, contained 58 per cent of nitro-glycerine and 37 per cent of nitro-cellulose. In making propellants for small-arms and shot-guns, other substances are introduced to moderate the explosion and to reduce the flash. A very brilliant flame is produced by gun-cotton and nitro-cellulose; this, together with some of the erosion, can be prevented by the introduction of nitrates in small quantities. Nitro-glycerine produces about 10,000 times its own volume when exploded.

Cordite is not a high-explosive, the substance burning evenly and, comparatively, slowly. Tri-nitro-toluene, produced by the action of nitric acid on "toluene" is a high-explosive familiarly known as T.N.T. It is interesting to note that the mono-, di- and tri-nitrotoluenes had been used for some time in the dye industry before they were recognized as explosives. As with nitro-glycerine, sulphuric acid is mixed with the nitric acid in the treatment and,

of course, the greatest precautions have to be taken to prevent the temperature rising beyond the safety point. Tri-nitrotoluene separates out as an oily liquid which solidifies when cooled. At ordinary temperatures it is extraordinarily safe to handle, but any impurities in it tend to increase its sensitiveness to explosion by heat or percussion.

Lyddite, known as melinite in France and Germany, is a high-explosive also known as picric acid, which is prepared by the treatment of phenol with nitric acid. The substance is actually made by first treating the phenol with sulphuric acid and then replacing the sulphuric acid with nitric acid. Its chemical name is tri-nitrophenol and it crystallizes as yellow crystals or flakes. It is a dye, and also a medicine, being used for the treatment of burns because it reduces the pain by anæsthetizing the nerve-endings. It produces a very violent explosion, but seems to have gone out of fashion in recent years owing to the discovery of safer and more easily handled explosives. The manufacture is more difficult than that of T.N.T.

Another explosive used in shells is ammonium nitrate which can be detonated. Generally it is used in combination with T.N.T., the mixture being known as amatol. Its greatest advantage is that there is no carbon left after the explosion. Ammonium nitrate appears to have been the "secret" of the new German bombs which were reported to have caused considerable havoc by the power of their detonation when used in Spain. In the case of high explosive, damage is not only done by the striking of buildings and people by actual fragments of metal or even flying bricks,

but by the pressure-wave of air set up. The detonating effect of these bombs is said to have extended for a quarter of a mile round the point of explosion.

In this latter instance, the ammonium nitrate was, according to reports, mixed with powdered charcoal and powdered aluminium. If this is the case, the explosive is one that has been used for blasting operations in mining for some time. The power of this explosive depends upon the tremendous amount of heat evolved when powdered aluminium is oxidized. The percentage of charcoal is very small and the amount of aluminium powder used is varied in accordance with the maximum temperature desirable. In mines, where it is necessary to keep the temperature down, the percentage is only 2 or 3. This explosive has a very high "velocity", over 4,500 yards a second. This means that a large amount exploded would become gaseous instantaneously and produce a shattering effect.

It has also been suggested that the explosive used in these bombs was liquid air. Because of the vast expansion that takes place when air is brought from hundreds of degrees below freezing point to the heat of ordinary combustion, liquid oxygen provides a violent explosive which has been used both for military and mining purposes. The great advantage of liquid oxygen as an explosive is its cheapness. Its disadvantage is the instability of the liquid oxygen, which is not safe for ordinary handling, as an accidental fall might cause explosion. There is the further difficulty that it evaporates and must therefore be newly made when used. This means that for all practical military pur-

poses, the liquid oxygen must be made on the spot, while it is quite impossible to use it in shells, since for shock of firing the shell would explode it and burst the gun-barrel. This disadvantage does not, of course, apply to aerial bombs which are "fired" merely by being released. The sensitivity of the explosive is, however, such that a single shot striking an aeroplane carrying liquid oxygen bombs might result in the whole cargo being blown up. The manufacture of the explosive actually in the bomb does not yet seem practicable.

This great disadvantage of shock does not apply to the use of liquid oxygen as an explosive in mining. For this purpose the liquid is absorbed into some combustible paper and fired by a detonator, the liquid being prepared on the site by a portable apparatus. In this case the fact that the explosive rapidly loses its efficiency owing to evaporation is a positive advantage, for it means that if a shot fails to explode, it can be dug out with perfect safety after a brief interval.

The French, in the Great War, tried an ingenious bomb using liquid nitric oxide in place of liquid oxygen. The explosive was actually manufactured during the flight of the bomb. The bomb had two separate compartments, one containing petrol and the other liquid nitric oxide. Pressure of the air on a small propeller in the bomb opened the two compartments immediately the missile was released and the two liquids flowed together. Nitric oxide is a violent oxidizing agent and the mixture formed an exceedingly sensitive explosive which detonated as the bomb

struck. No detonator was required, the impact itself being sufficient.

These are some of the explosives used for military purposes. A simple explosive is rarely used, a mixture enabling control over the explosion to be exercised. The perfect explosive would be one that was perfectly safe to handle, that did not explode with slight shocks such as might be experienced in transport, and which produced a great amount of gas or heat at a speed that could be easily controlled. Ideally, no deposit would be left, the mixture being completely converted into gas so that there need be no smoke or corrosion of gun-barrels. In practice, the perfect explosive remains to be discovered, but continuous research during the last fifty years has led to the production of a variety of explosives for special purposes, the action of which can be exactly forecast.

The degree to which control can now be obtained is shown by the use of dynamite. By the careful placing of measured charges, it is possible to demolish buildings in well-populated areas without danger to their surroundings. The ideal explosive would also, from a military point of view, be silent, but this is a virtual impossibility. Explosion infers the setting up of a pressure wave of air and as sound is simply the vibration of air, to ask for a silent explosive would be like asking for a bell that could be struck without any sound. The most that can be hoped for is the invention of expansion chambers which will reduce the amount of sound produced by variations of barrel pressure. In this respect silence might be regarded as the production of "continuous sound".

So far we have dealt with two main classes of explosive: propellants and high explosives. There is a third class which can be called detonators, from the purpose for which they are used. These are explosives which are exceedingly sensitive and generally unsafe to use for filling shells because of the ease with which they are fired by shock. But, employed in very small quantities, they are suitable for initiating the explosion of a less sensitive explosive.

The best-known detonator is fulminate of mercury. This was discovered some fifty years before nitro-cellulose, but the sensitiveness it showed made it useless as a practical explosive for cartridges and, of course, if a shell were filled with it, the shock of being propelled from the gun-barrel would result in premature explosion. It could not be used to fire gun-powder, because its violence merely resulted in the grains of powder being scattered. Nearly a century had to pass before practical use for it was found in "starting" T.N.T. and similar high explosives. The fulminate itself is fired by percussion of a needle moved by impact with the target or by a time device so that the high explosive in the shell would, in turn, be detonated. A similar powerful explosive is lead azide, which is one atom of lead combined with no less than six of nitrogen. The mere breaking of a crystal of this salt is generally sufficient to effect its explosion.

The production of suitable explosives is, of course, only half the story of ammunition. The remaining work, closely connected with manufacture, is the placing of those explosives in the most convenient or effective form for firing at the enemy. For a long time after the

invention of gunpowder, ammunition was of the simplest kind. A gun was loaded by placing in it a charge of gunpowder, compressing this to obtain even burning by means of a ramrod, inserting a wad, and then the bullet or cannon-ball which, only approximately, fitted the bore. Firing was by igniting the gunpowder through a small hole drilled in the barrel at the breech end.

In the case of artillery, the advantages of a projectile which itself exploded on reaching the target was realized and various primitive forms were evolved. These generally depended upon some form of gunpowder fuse to explode them after a certain period. In some cases the fuse was lit by the gunpowder which propelled the shot, this fuse being little more than a trail of gunpowder incorporated in the projectile. The time elapsing before explosion was very uncertain and it was common for such shells to "fizzle" on the ground for an appreciable time before exploding. Shrapnel was invented towards the end of the eighteenth century, differing from previous projectiles in that it had a bursting charge to open the projectile and release the small bullets contained. This shell was not fired at enemy troops, but over their head, so that it rained down the bullets.

The discovery of fulminate of mercury which would explode on contact with a target opened up the way to the percussion fuse which had been suggested centuries before but had been impossible to realize because no suitable chemical was known. Shot developed rapidly until it was completely superseded by shell. To-day, shot of any kind are rarely used in

war, being limited to proof shots and paper shots for practice, but it is interesting to note that certain types of chain or strip shot have been again suggested for anti-aircraft guns.

The evolution of ammunition for small arms was comparatively simple as is mentioned under the subject of rifles. In the case of artillery, ammunition is naturally more complicated, for in addition to propelling the projectile from the gun it must have the means of igniting the charge of explosive and of deciding the moment at which this ignition will take place.

I have dealt with the explosives used as propellants and need here only mention the manner in which they are employed. The tubes, cords, or whatever it may be of explosive, are packed in silk bags. Because they are difficult to ignite, a small charge of gunpowder is sewn on to the end to start the explosion. In the case of cordite charges, they are sometimes made with hollows, for the material only burns at the surface and the hollows ensure not only even burning but, by their design, the ignition of a bigger and bigger surface so that the projectile is evenly accelerated. This type of charge, with various explosives, is used for all artillery except that classed as quick-firing which carries its propelling charge in a metal container, generally brass, which is either separate or attached to the projectile. The advantage of this is quickness in loading, greater safety and simplification of the breech; but the greater weight makes this principle almost impossible for large guns.

There are three chief methods of firing the charge.

In the case of big naval guns this may be done electrically, or a tube containing fine grains of powder may be inserted in the breech and fired when struck by the "trigger". In the case of quick-firing guns, a cap is incorporated in the base of the charge which is fired by being struck, the flash igniting the powder, which in turn fires the propellant.

The projectile itself varies enormously in construction according to the purpose it is designed to achieve. High explosive shell is intended to destroy by detonation, to blow up buildings, fortifications and men, in the same way as an explosive charge in a mine breaks up rock. The shell fragments themselves may do damage. Shrapnel, by bursting into a large number of pieces and distributing bullets, is intended solely to put men out of action. The gas shell distributes poison gas, smoke shells generate smoke for concealment and star shells illuminate the area immediately beneath the point of exposure. For naval use and for service against tanks there is armour piercing shell which has a casing of specially hard steel intended to penetrate armour before exploding. Ordinary high explosive shell would be turned back by the armour and have little or no effect on the men or guns protected by its covering. There is also a soft-nosed shell which does not spread like a bullet but which distributes the striking load in order to prevent fracture before penetration.

Various types of fuses are used but they fall roughly into four classes: those which are worked by percussion on the nose of the shell, those worked by percussion independent of the nose, those worked by slow

combustion and those worked by mechanical device.

The direct action fuse is fired when the shell receives a blow on the nose. The ordinary British shell has inside its nose a hammer which when it is struck by impact with the target, forces down a point onto the detonator, cutting through a piece of copper wire support. Between the detonator and the exploding charge is a safety shutter which opens after the shell has left the gun. This fuse is exceedingly sensitive, only a slight blow being required to work it. There are various safeguards, apart from the fact that the fuse itself is only screwed onto the projectile shortly before firing. A safety cap prevents any accidental blow on the head firing the shell. This cap is removed just before the shell is loaded. A collar prevents the hammer-head bearing onto the detonator even after the safety cap is removed and this collar is not released until the shell has actually left the barrel, the forward movement tearing off a safety tape which takes the collar with its "pull".

When it is desired that the shell shall explode as soon as its velocity is checked or it "gazes" a target, the method is different. The mechanism is rather complicated, but essentially the principle is that a small pellet inside the fuse is shot back by the sudden check in speed of the forward motion of the shell. This pellet contains the detonator which strikes a needle and is exploded. Various safety devices are incorporated to prevent the fuse igniting prematurely. For instance, the centrifugal force imparted by the spin of the shell is utilized to open out a series of brass leaves which have prevented the pellet

under any circumstances coming in contact with the needle.

For certain types of shell it is not desirable that there should be explosion on contact. In the case of shrapnel, for instance, the explosion is required to take place when the shell has reached a certain point in the air, with armour-piercing shells, or shells intended for demolition, it is necessary that explosion should take place after the shell has penetrated and come to rest at some depth.

The simplest form of time-fuse is really a train of powder such as was used in the old shot. For simplicity in setting, the modern form has a train of powder set in grooves, the length of the train and, therefore, the time to elapse between the firing of the projectile and explosion, being altered by adjusting rings. The shell can be "set" to explode after any given interval of time, the powder in the fuse being ignited by the firing charge.

Time-fuses can also be made to act mechanically, the mechanism being similar to that of a watch. After so many revolutions of a wheel carrying a needle which bears downwards, the needle is released, strikes the detonator and explodes it. The mechanism is exceedingly complicated but has been made sufficiently robust to withstand the shock of firing, a straight spring taking the place of a hairspring which would be upset by the centrifugal forces set up by the shell's rotation in flight.

There are other types of projectiles we have not yet considered: bombs, torpedoes and depth charges. The chief difference between an aerial bomb and a

shell is that the former are not required to withstand such high strains during projection. A shell leaving the muzzle of a gun is travelling at about 1,200 m.p.h. and it has been accelerated to that speed from nothing in a fraction of a second. A bomb being dropped, soon reaches a maximum speed which is less than half this pace, but the acceleration is constant and there is no shock. On the other hand, if the bomb is to reach its objective as quickly as possible, it must offer the minimum of resistance to the air and it is therefore carefully streamlined. Vanes in the tail ensure that it falls head first. Fuses very similar to those used on shells are employed to explode the high explosive in a bomb, the difference being that small vanes are used to wind them up, thus providing a safety device. The striker is not released until a definite number of revolutions have been made. In some cases pins are also used to prevent the possibility of accident.

As with shells, three chief types of bomb are used according to the destruction desired: large bombs with a big charge of high explosive are called demolition bombs and their effect is chiefly secured by blast. These are used against buildings, fortifications or similar works. Fragmentary bombs are usually much smaller. They depend for their action upon the mass of flying metal and are intended for use against troops. Gas and chemical bombs are also used, but they are largely untried in their effects.

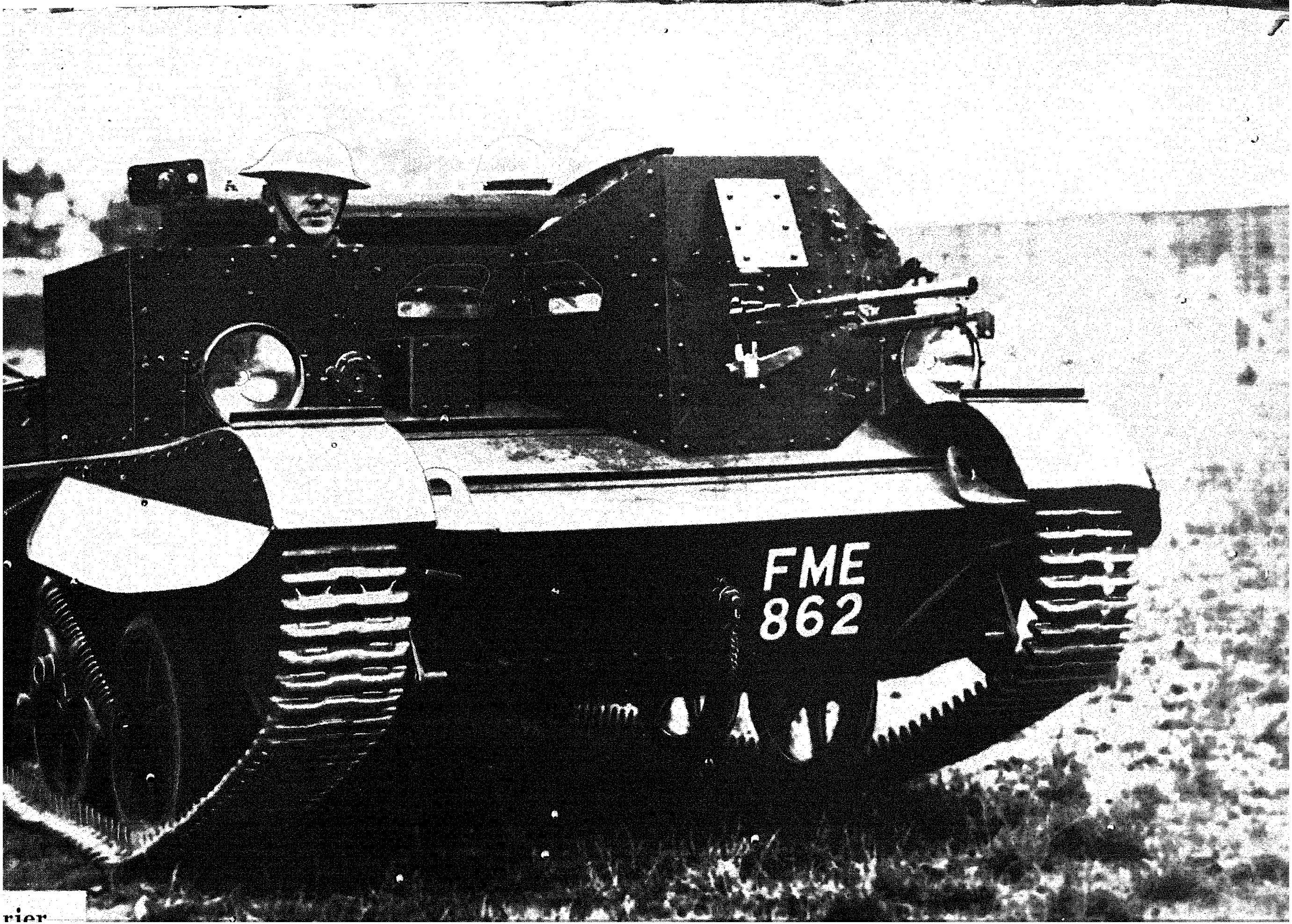
Bombs usually have fuses both in nose and tail. For demolition bombs the fuse is arranged to detonate immediately on contact or after the elapse of a short

period of time to allow for penetration. Fragmentary bombs have fuses designed to act on contact.

A new type of bomb, the importance of which has recently increased greatly, because of the possibility of using it against civilians, is the incendiary bomb. Very small bombs containing incendiary material, generally thermit, are capable of starting fires. The bombs themselves are not easy to extinguish since they do not depend upon oxygen for combustion and are not naturally extinguished by water or sand. Thermit is mostly a mixture of aluminium powder and iron oxide. When these are ignited, the heat generated in the formation of aluminium oxide and metallic iron is tremendous, about 2,500 degrees centigrade. This heat means that bombs will burn through metal and certainly through wood beams, igniting them as they pass.

Incendiary bombs are usually quite small, containing about 2 lbs. of thermit. This is sufficient to start a fire and the theory is that an aeroplane carrying, say, 1,000 2-lb. bombs is likely to do more damage by creating a number of small fires than by carrying ten 100-lb. bombs which might start one big conflagration. Fire extinguishing is one of the most important functions of those concerned in minimizing the effects of raids on non-military objectives and the idea is that so many fires should be started simultaneously that it will be impossible to deal with them all. This is essentially a weapon for use against ordinary houses, office buildings and so on.

At first sight this type of bomb would seem to be disastrous in its effect. In actual practice the fire bomb may not prove to be such a deadly weapon, for a



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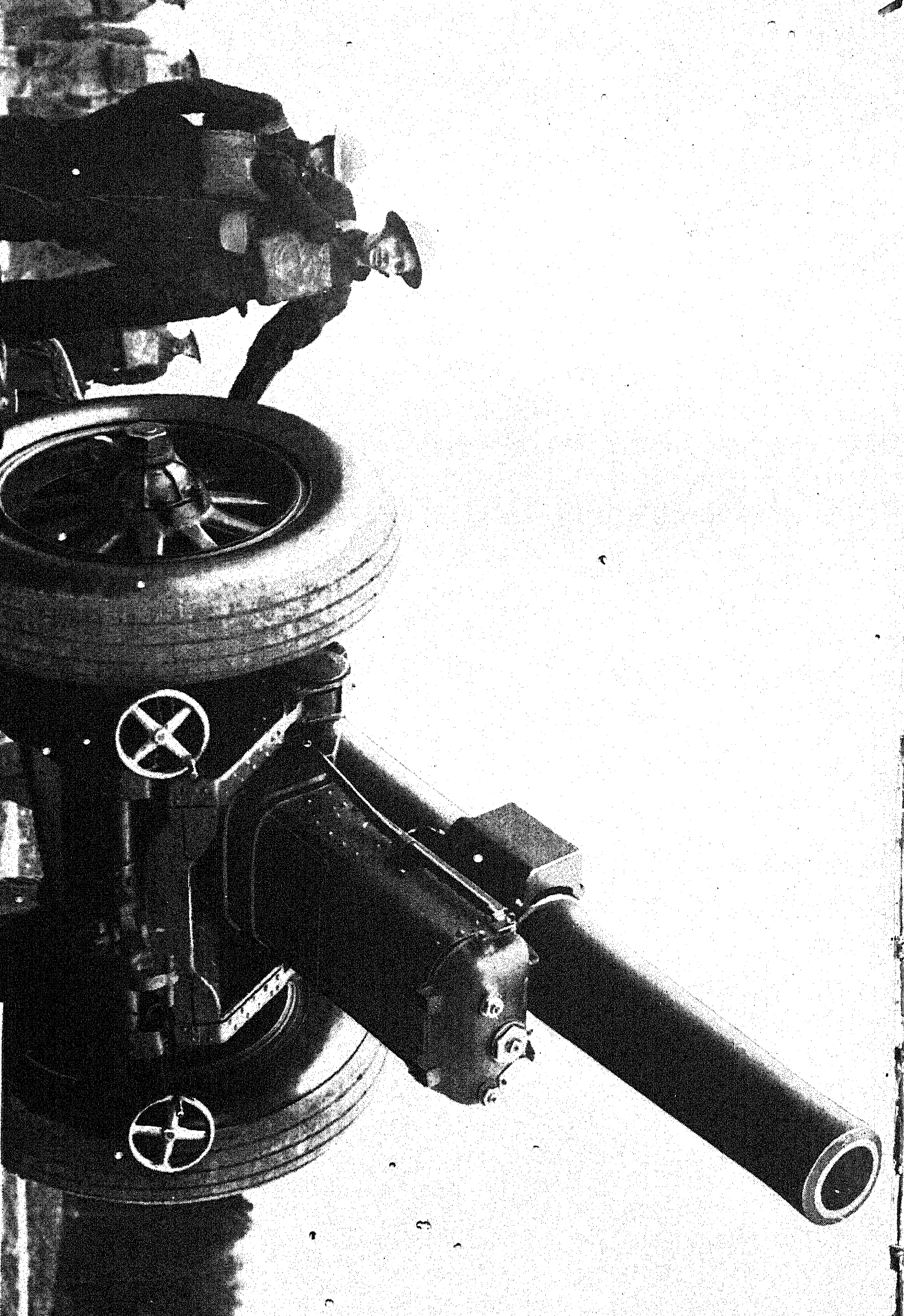


number of reasons. Extinguishing apparatus has been devised. By the mere laws of chance a considerable number of the bombs are likely to fall in places where they will do no damage, in streets, gardens and open spaces. The actual proportion of suitable spots for causing a fire is comparatively small when the total area of any town is considered, and there is not much chance of aiming small incendiary bombs with any real accuracy. The standard method of handling an incendiary bomb is to shovel it into a bucket of sand. Special equipment with long handles is necessary as the intense heat makes it impossible to approach close to the burning material. Placed in the open air, the bomb will soon burn itself out. It is possible that actual experience would show it necessary to use larger incendiary bombs and this, of course, would reduce the number that could be carried. The construction of the incendiary bomb follows that of high explosive bombs, except that the explosive charge is very small, being just sufficient to break the container, ignite and scatter the incendiary mixture.

There is another type of bomb which, after becoming obsolete for nearly a century, returned to be one of the most effective weapons in short-range fighting during the Great War. This is the bomb that is thrown by hand or fired by a rifle, generally called a grenade. Grenades, of course, gave the Grenadiers their name, but the grenades used during the seventeenth and eighteenth centuries were fired from guns, whereas the modern type are thrown or fired from a rifle. The hand-grenade consists of a miniature shell which is exploded by a fuse worked on the time

or contact principle. A contact fuse is the best from one point of view because there is no warning period during which it may be picked up and thrown back, but the possibilities of the grenades being dropped are so great that the time-fuse is in general use. Many different ways of starting this time-fuse were used, some depending upon the end being "struck" like a match against an igniting surface.

Perhaps the most effective bomb is the Mills hand-grenade in which the fuse was not started until the bomb was actually in the air. The fuse runs for five seconds so that if the bomb should be dropped after the safety pin has been withdrawn, there is a chance for the people near to take cover. The fuse itself is fired by a striker actuated from a powerful spring. This spring is released by letting go a lever which is held in the hand close against the grenade until it is thrown, when the released lever sends the striker against the detonator. Powder then burns for five seconds before reaching the high explosive and fragmenting the bomb. Accidental release of the lever during transit, or before the grenade is immediately required, is prevented by a safety pin which holds it in position and is not drawn out by means of its ring until immediately before throwing. Like other projectiles, the bomb can be filled with high explosive, gas or smoke-producing chemicals, the former being by far the commonest.

The importance of land or trench fighting is not likely to decrease in spite of modern aerial warfare, so that bombs of new type are being constantly introduced. Attempts have been made to construct bombs

which roll over trenches after discharge while others have been successfully controlled by radio to explode at a given signal. As invariably happens, defence follows so quickly in the train of new principles of attack that it is impossible to define which may ultimately prove to be the type of bomb to carry the greatest load of destruction in its wake.

CHAPTER III

SMALL-ARMS

EVER SINCE the introduction of explosives into warfare, it is small-arms that have been the most important weapons. The rifle is still the most widely used weapon in every army and, in spite of developments with automatic guns of various kinds, it is likely to remain the main weapon of the foot soldier for many years to come. The introduction of special types of small-arms, notably the anti-tank gun, has reduced the gap between small-arms and artillery, but the distinction still exists.

The most important consideration for a gun which has to be carried and used by one man, is the method of firing and loading; the story of the gun from the first arquebus to the modern military rifle is the story of the improvement of devices for facilitating loading and firing. The one other vital difference between the modern rifle and the old musket is the rifling which gives the modern weapon its name.

The method of firing the earliest guns used by infantry was the same as that used for cannon. A hole in the side of the rear of the barrel allowed powder on a pan outside when ignited to fire the charge and

force out the bullet. For more than a century the method of igniting the "priming", as this powder outside the barrel was called, was to light it with a match so that, as might be imagined, firing was both slow and uncertain. Indeed it was almost impossible in rain which damped the powder. Because the constructional metal used was not very strong, a considerable weight of it was required, the marksman often using a stand to support the front of his gun. Altogether it is remarkable that he ever managed to hit anything, and it is not surprising that infantry were not particularly feared by the cavalry which then reigned supreme. At most they could get off one volley before the cavalry were upon them, and they required a screen of soldiers armed with pikes to cover their front.

The first improvement in small-arms came with the invention of a method of igniting the priming which did away with the necessity for the clumsy ignition of the priming by a match. This invention was the wheel lock, made in the sixteenth century and it worked very much like a modern automatic lighter. When the trigger was pulled, a spring was released which turned a steel wheel against a mineral to produce a spark which, not always, ignited the priming powder. A hundred years later this was followed by an invention which held the field for more than two centuries, the flint-lock. The advance made with this device was not limited to the use of flint, but also to a mechanism which kept the priming covered until the actual pulling of the trigger, a cover being lifted off to allow the powder to be ignited. Flints are still exported from England for use in flint-lock guns in some of the more

remote parts of the world and this type of gun was the infantry weapon of Britain until a hundred years ago.

The flint-lock was made obsolete by the invention of the percussion cap. Gunpowder has to be ignited by an actual spark or flame, but there are other explosives that are fired by detonation. The percussion cap makes use of one of these to produce the flame necessary to ignite the gunpowder. This is the principle used to fire all these propellant charges to-day, although the method of using it has changed. With the coming of the percussion cap, made possible by the discovery of detonating chemicals at the end of the eighteenth century, the function of the trigger was no longer to rotate a wheel or strike a spark, but to fire a cap in much the same way as a boy's pistol is fired. At first, actual percussion caps were used, but the convenience of the cartridge in which percussion cap, propelling charge and bullet are held together, led to the disappearance of the separate cap. With the coming of the cartridge went the touch-hole which had been part of every firearm for more than three centuries. The elimination of this resulted in greater power, for a certain leakage of gases had always taken place at this point.

The first cartridges were of cardboard, but metal cartridges were introduced in the " 'sixties" and " 'seventies" of the last century. The vital change introduced by the cartridge was, of course, breech-loading. Up to that time, loading had meant placing a charge through the muzzle of the gun and ramming a bullet on top of it, always slow and laborious and

necessitating the carrying of loose powder and bullets. The one difficulty in the use of the cartridge was ensuring that the end effectively sealed the barrel so that the gases could only escape forward, pushing the bullet in front of them. The metal cartridge expands when fired, owing to the heat, and ensures sealing. The rim of hard metal at the rear of a cartridge is to make extraction easier.

The next important step after the introduction of breech-loading and cartridges, was the invention of the magazine or clip. The saving in time that would result if a number of cartridges could be loaded together was obvious, but the difficulty was to find a device that was "fool-proof" under the very difficult conditions to which a service rifle is subjected. The invention of the cartridge had been accompanied by various methods of extraction of which the one that has survived is the bolt. Non-technically, what happens is that a grip on the end of the bolt takes hold of the rim of the cartridge and when the bolt lever is worked it first turns for loosing and then pulls out or ejects the spent cartridge. This is, of course, only one function of the bolt which also contains the firing pin. When the bolt is pushed forward, a spring is compressed against the firing pin which remains stationary and is not released until the trigger is pulled.

A clip of cartridges generally contains five which slip easily into a magazine in front of the trigger guard. At the bottom of the clip is a spring, forcing the cartridges upwards. When the bolt extracts the cartridge fired, the next is forced upwards by the

spring, ready to be pushed into firing position by the bolt on its return. This continues until the last cartridge has been fired, when the clip drops back.

Very rapid fire is possible with the modern bolt action rifle, for it does not have to be removed from the shoulder to be loaded each time. The British weapon is the Lee-Enfield which, with minor improvements, has been used for more than thirty years. Its enormous success in the hands of trained soldiers was demonstrated in the early days of the Great War when rapid fire with rifles was so considerable that the enemy imagined they were facing machine-guns.

So far I have, for the sake of simplicity, omitted any mention of the grooves or rifling in the barrel, which gives the modern rifle its name and really distinguishes it from the musket. The advantages of imparting a spin to a bullet to keep it on a straight course were recognized very early, and the method of making grooves in the barrel which forced the bullet to turn in its forward movement was known as early as the sixteenth century. The chief difficulty was that the gunpowder of the time left such a deposit in the barrel that considerable force had to be used to force the bullet into place. This took time and outweighed the advantages secured, from a military point of view. Until comparatively recently military small arms were practically "point blank" weapons, that is, they were fired at large targets at close range. Troops were trained to hold their fire until missing was almost impossible. This was successful to a point, so long as troops marched forward shoulder to shoulder, but it accounted for the comparative failure of troops in

dealing with savages or woodsmen who took cover and advanced in ones and twos. But the prejudice against "aimed" firing continued. There is an amusing story of an old officer who, when it was suggested that the Irish should be taught to aim their fire, said: "If you teach them to aim, there won't be a landlord left in six months."

Another reason why rifling was not of such great importance was the comparatively low muzzle velocity imparted by gunpowder. The range of muskets was limited and they were sighted for 100 or 200 yards. At a range of 200 yards they had a comparatively high trajectory. With the coming of cordite, muzzle velocities went up by leaps and bounds so that not only rifling but streamlining of the bullet became important. Many experiments were tried before the most satisfactory arrangement for imparting a spin was discovered. The number of grooves and the number of turns they made in the length of the barrel was varied. The rifling of the standard army rifle to-day is of square section and makes a complete turn in 10 inches. The bullet is mostly of lead to secure the maximum weight, but the covering is of a special soft alloy which fits the grooves and ensures rotation.

For many years bullets were invariably round because a spherical shape gave a fairly true flight. But the advantages of the elongated shape, by lessened air resistance for a given weight, became apparent and bullets were slowly elongated until they were cylinders with rounded heads. The majority of bullets to-day are boat-shaped which gives an increased range although there undoubtedly remains oppor-

tunity for improved streamlining in the light of modern research.

At the same time, over the course of the last century, there has been a great reduction in the calibre of the bullet used. A hundred years ago the Rifle Brigade were using a bullet with a calibre of .704, which was the weapon used in the Crimean War. This has been reduced to less than half and the modern Lee-Enfield is a .303. The advantages accruing are not limited to the increased range obtained and the reduction in the propellant charge required. The weight of each round has been considerably reduced and when this is multiplied by 60, the number of cartridges a soldier might be expected to carry, the saving in weight is considerable. There is a limit to the reduction in calibre that can be made if the rifle is to be effective and one of the modern army revolvers, a short-range "man stopping" weapon, is 0.455 or nearly half-an-inch, firing a heavy bullet.

The competition of modern warfare has made continuous demands upon the ingenuity of the inventor, and the production of the bolt-action rifle using a magazine of cartridges only emphasized the need for an automatic rifle for military purposes. The automatic rifle can be distinguished from the bolt-action rifle by the fact that no movement except pressing the trigger is required to fire a succession of shots. Automatic rifles can be divided into two classes, those fully automatic in that one depression of the trigger results in shots being fired until pressure is released, and the semi-automatic in which a separate pull of the trigger is required for each shot, but no movements on

the part of the marksman are called for to put the two successive rounds in place.

Two forces in the rifle can be tapped to provide the energy required to pull back the firing pin and insert a cartridge between each shot. These are the force of the explosion or the expanding gases and the recoil of the gun. All automatic rifles and machine-guns use one or other of these methods, and some use both.

There are considerable difficulties in the way of producing an automatic rifle suitable for military use. To be considered as a rifle, the weapon must be capable of being easily handled by one man, which means it must weigh somewhere in the neighbourhood of 10 lbs., it must be able to take a bayonet for hand-to-hand fighting and its mechanism must be sufficiently robust to withstand the hard use to which it is likely to be subjected in the field. One of the great beauties of the military bolt-action rifle is that it can be taken to pieces very quickly for cleaning. So far no nation has solved the problem of producing a satisfactory automatic rifle, although the new United States Garand rifle is said to meet the requirements of a semi-automatic military rifle. The details of this weapon with which the United States infantry is to be equipped in the near future in place of the Springfield rifle which they have used since 1903, are necessarily secret, but it is gas-operated, about the same weight as the ordinary rifle, takes a bayonet and fires about 50 shots a minute. Experienced marksmen are said to have got off between 80 and 100 shots a minute. Taking into account the fact that this rifle can be mass-produced at about £10, the same cost as the ordinary rifle, it repre-

sents a remarkable achievement. The rifle is semi-automatic in the sense that a separate squeeze of the trigger is required for each shot. It is doubtful whether a fully automatic action would be desirable for an infantry rifle, since it would result in an enormous expenditure of ammunition and would impinge on the province of the machine-gun without its comparable efficiency.

The Bren gun, recently adopted by the British army, is not an automatic rifle but a light machine-gun. It is fired from the shoulder, but requires a rest. It is not a substitute for the ordinary rifle, or for a machine-gun, but an accompaniment of both with its special uses. The heavy machine-gun, weighing at least 50 lbs. and requiring a tripod weighing possibly an equal amount, is primarily a defensive weapon for the simple reason that its weight necessitates comparatively slow movement. Moreover it requires the attention of a team. The need for a light machine-gun was revealed in the Great War and the Lewis gun did admirable service. The search for a better type of light machine-gun resulted after many years of trial in the adoption of the Bren in 1934, with modifications made by the Royal Small Arms Factory. The Bren gun at 21 lbs. weighs 10 lbs. less than the Lewis gun. It fires a magazine of 30 cartridges at a theoretical speed of 550 a minute, but the time taken in changing magazines reduces the actual number that can be fired in any minute to about 120. A simple device enables either single shots or continuous fire to be maintained.

The method by which the Bren gun works is worth describing for although it represents a great advance

in some ways, the principles are the same as for all gas-operated guns. Below the barrel is a "gas-chamber" connected with the barrel of the gun by a hole which is only uncovered when a bullet passes down, the bullet thus acting like the valve of an engine. Opening the valve results in a quantity of gas, the gas, of course, is produced by the explosion of the propellant charge and is what is responsible for the bullet being driven out of the gun, entering the chamber, the exact amount being regulated. Here, the gas forces a piston backwards towards the butt of the gun, and a mechanism connected to the piston ejects the last cartridge. The exhausted gas is allowed to escape and a powerful spring then forces the pistol forwards, the movement pushing a fresh cartridge from the magazine into firing position.

Firing a rifle produces a good deal of heat, even an ordinary rifle will become unbearably hot after rapid fire. With a machine-gun this heat is a considerable problem and provision must be made for cooling or the gun will become unusable. Moreover, wear inside the barrel becomes much greater at high temperatures, in spite of special bullets. In the light machine-gun it is impossible to adopt the water-cooling systems of heavy guns because of the weight involved. In the Bren gun cooling is secured by changing barrels and one of the beauties of the gun is the simplicity with which this can be accomplished in a matter of seconds without the use of tools. The wooden handle which you see on top of the barrel is not only for carrying the gun, but also for catching hold of the barrel when it is hot. The apparent expansion of the barrel at the end

is really a separate piece of metal fitted over the mouth of the barrel to eliminate flash for night firing.

Making a light machine-gun is, of course, considerably more involved than making a rifle and the engineering achievement of turning out Bren guns by the hundred within a comparatively short time of their adoption can be judged from the fact that for checking the gun body alone some 550 different gauges are required.

It would not be desirable, even if it were possible, to arm every infantryman with a light machine-gun. Nor will the light machine-gun result in the disappearance of the heavier types which, using belts holding 250 or more cartridges, are able to sustain fire for longer periods.

The story of the machine-gun goes right back to the earliest days of firearms, but until the adoption of the percussion cap and cartridge, little progress could be made. Inventors had to expend their ingenuity in devising means of bringing a succession of loaded barrels in front of a firing point. Obviously this limited very severely the number of rounds that could be fired and made loading a long job. One of these guns had 31 barrels, but these were fired simultaneously. Machine-guns, indeed, until the invention of the Gatling gun were really batteries of rifles.

The Gatling gun had ten barrels, but was fed by gravity the bolts being worked by the continuous turning of a handle. It had a very high rate of fire, theoretically 600 rounds a minute, and was used in the "'sixties" and "'seventies" of the last century. Similar was the French *mitrailleuse* with 37 barrels fired in

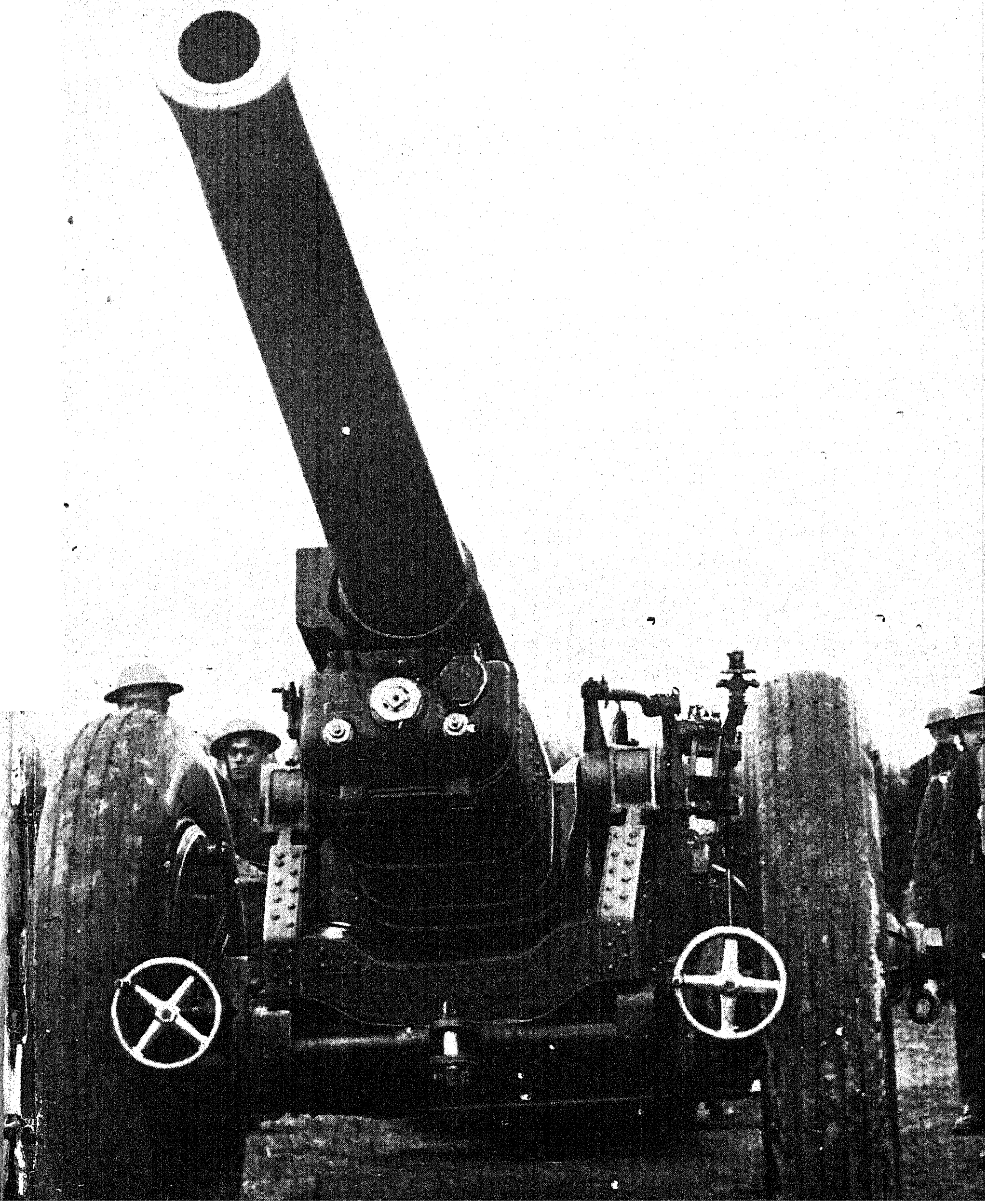
succession, but these guns and other of similar principle were made obsolete by the invention of the Maxim. This gun, instead of calling for manual operation of a crank, for the first time made use of the force of the recoil of a single barrel to eject a cartridge and draw back the bolt. It also introduced the belt feed, in which cartridges in a cloth belt were fed automatically to the gun. In the British army it was being superseded at the beginning of the war by the Vickers which makes use of gas pressure as well as the recoil and the Vickers is, for some purposes, now the standard machine-gun. The principle is very much the same as with the Bren gun, except that there is a heavy "mainspring" which is wound by the backward push of the piston in response to gas pressure, and that the recoil is also utilized. The gun is water-cooled, the barrel being jacketed for almost its whole length; a simple device carries off the steam produced to be condensed and returned to the radiator. Some other machine-guns are air-cooled with heavy metal "fins" like those on a motor-cycle engine.

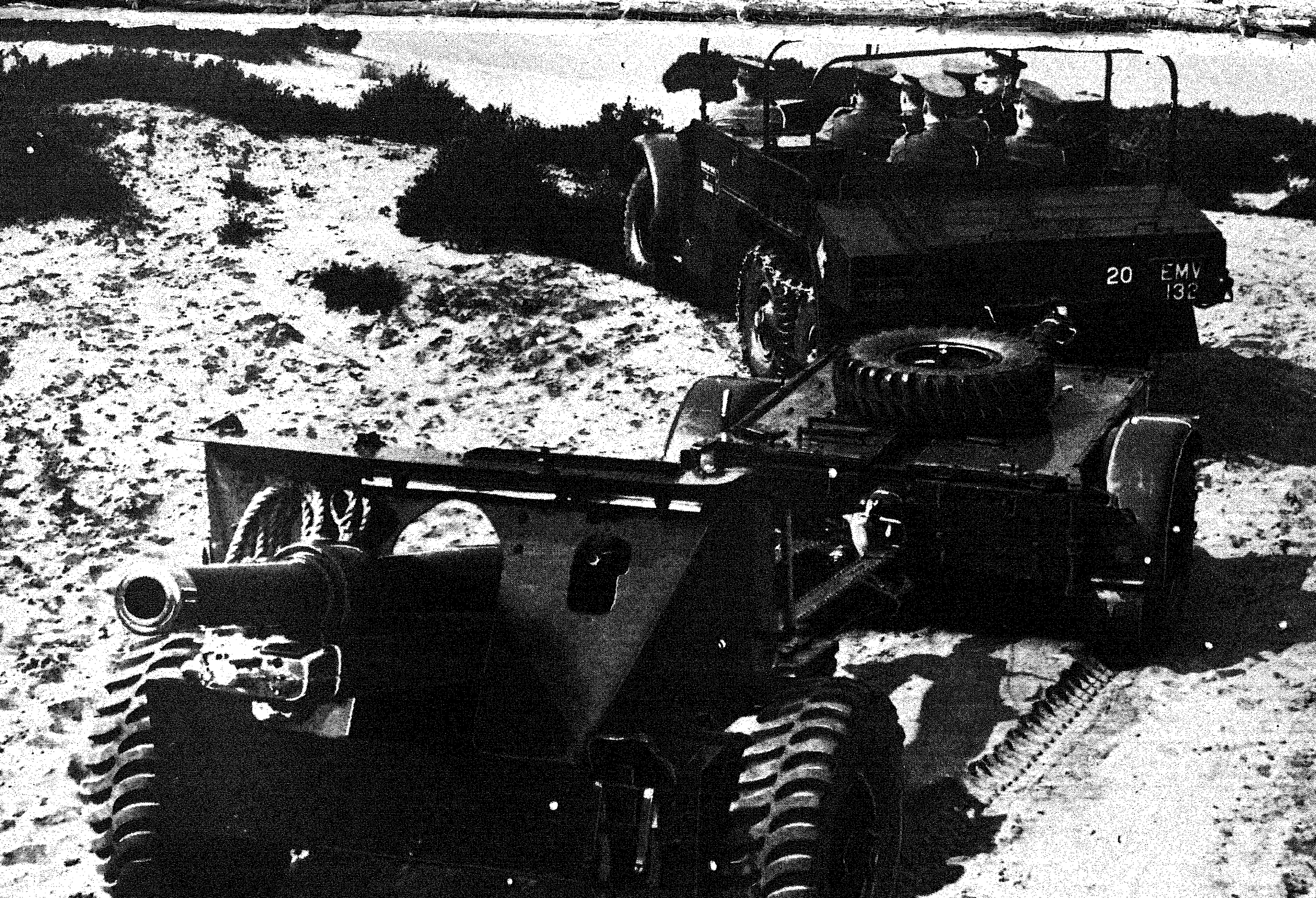
A very important point with all small-arms is the "locking" of the breech at the moment of firing. It is essential that the gun should not be fired until the cartridge is held firmly in position and the breech closed so that it cannot fire backwards. This is secured by studs on the bolt which "lock" it in position.

Modern rifles and machine-guns have muzzle velocities of 2,500 feet per second and upwards and a useful range of well over a mile, being sighted from 200 to 2,000 yards. The great increase in muzzle velocity has resulted in a comparatively flat trajectory, but the

trajectory is only "flat" for a limited distance and sights, therefore, have to be altered for the varying distances. It will be appreciated that if the rear sight of a gun is lowered in relation to the front sight, the effect will be to have the barrel pointing slightly above the target on which it is "levelled". The sights are carefully marked to allow for the necessary curve, taking into consideration the characteristics of the cartridge, so that the marksman continues to sight his rifle on the target instead of having to allow for dropping. Some rifles, notably those of the U.S.A., also have a wind-drift gauge which makes allowance for the effect of the wind on a long shot.

Regarding the future of small-arms, the experience of the U.S.A. with the new semi-automatic rifle will, no doubt, be watched with interest by other nations. Still greater muzzle velocity may be obtained by the adoption of slightly tapering barrels so that the bullet is actually compressed and no leakage of gas can possibly occur. The additional power is desirable, perhaps, not so much for increased range as for the penetration of armour. The coming of the tank has called for small-arms capable of penetrating steel. But on the whole the fact that none of the nations during the Great War found it necessary seriously to alter their chief weapons suggests that there is little immediate room for improvement within the conditions imposed.

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CHAPTER IV

ARTILLERY

THE INVENTION of artillery quickly followed on the discovery of gunpowder in the thirteenth century. The manufacture of large cannon was, in some ways, easier than that of small-arms, for the great weight of metal required, owing to the poor strength of the iron available, was of less importance in cannon than in a musket to be carried and held by one man. It is impossible, without great technicality, to deal adequately with the evolution of the vast number of different types of guns used to-day from the primitive cannons of the fourteenth century. It will be more useful to describe some of the fundamental inventions which led to the modern big gun, capable of firing a projectile weighing a ton up to twenty miles and of the quick-firing gun which can fire a 28-lb. shell to a height of 40,000 feet fifteen times a minute.

The first problems of gun-makers were concerned with obtaining materials of sufficient strength to withstand the explosion of several pounds of gunpowder. Early guns were generally of copper, but wrought-iron quickly came into use the barrel being made by

welding together a number of bars which were then bound with hoops on the outside. Needless to say, accidents due to the gun breaking up when fired were quite common. The calibre of some of these guns was as great as that of the biggest guns of to-day, but, of course, they fired their stone or iron shot only a short distance, required a huge charge of powder and generally were nearly as dangerous to the gunners as to their enemies. Improved knowledge of casting led, in the sixteenth and seventeenth centuries, to this process being adopted for gun manufacture. The earliest guns had been breech-loaders, but improvements in gunpowder made these unreliable and muzzle-loading became universal. For all practical purposes a gun, from the sixteenth to the middle of the last century, consisted of one piece of metal, the barrel, with a hole in it at the back for igniting the charge. For a considerable period the cannon-ball fitted fairly loosely into the barrel so that gas escaped between it and the barrel, resulting in much waste of energy. It was not until the middle of the eighteenth century that serious attention was paid to this "windage" and attempts made to reduce it so that the whole force of the explosion might be devoted to propelling the cannon ball.

In fundamentals, very little change took place in cannon between their invention and the middle of the last century. Improved methods of aiming resulted from the beginnings of the science of ballistics with which we shall deal later on, and the invention of shell early in the nineteenth century made artillery more effective against infantry and wooden ships. In general,

the cannon in use at Waterloo and Trafalgar were much the same as those used to repel the Spanish Armada.

In the middle of the last century a great number of developments took place. Although these improvements arrived together it is simpler to consider them separately. The new designs concerned the introduction of stronger metals for the construction of guns, the introduction of rifling, the invention of fundamentally different methods of construction, the invention of breech-loading, and of automatic methods of loading or firing.

Gunmakers benefited from many advances in metallurgy and by the middle of the last century the metals available to them for construction were vastly stronger than the cast and wrought-iron that had been used for centuries. The advantages of boring out the barrel, instead of casting it hollow or welding it, had been appreciated in the middle of the eighteenth century and this was now the usual method of construction. Steam power made the boring less laborious and more accurate. The advantages of a cylindrical projectile over the round type became obvious with an elementary study of ballistics; greater striking power for the same muzzle velocity and greater range due to lessened wind resistance. The difficulty was that an elongated projectile fired from a cannon would turn over and over and be exceedingly inaccurate. It had long been known that rifling the barrel of the gun to impart a spin to the projectile would overcome this difficulty. The objection was that unless an effective method could be found for making the projectile

fit tightly into the grooves, there would be no spin and even greater windage.

The first effective rifled guns imparted the spin by having a bore which was a slightly twisted oval, but this was not satisfactory. There followed guns with grooves firing projectiles covered in lead, the soft metal being forced into the grooves and thus giving a tight fit. This led to the manufacture of projectiles fitted with studs which fitted into the rifling grooves and eventually of the driving band of copper or soft alloy slightly larger than the bore, the soft metal being pressed into the grooves. The projectile is then rotated in its passage up the barrel; it also effectively closes the barrel and prevents "windage". This is the method used with the guns of to-day. It was the necessity for rifling as much as the convenience that led to the invention of the breech-loading gun; obviously a projectile with a band slightly larger than the bore could not be forced down the barrel from its mouth. Moreover, the demand for longer guns to give greater range made the muzzle-loader very inconvenient for loading.

The problem of inventing a safe breech was not easily or quickly solved and, indeed, Britain's experience with early breech-loaders, which depended upon a screw being turned taut, led in 1864 to her reverting to muzzle-loaders for a short period. The problem of breech-loading was solved by the "interrupted screw". Instead of a full screw inserted into the barrel to close the breech, the block was fitted with studs which represented part of the thread of a screw. Thus a very small part of a complete turn was sufficient to lock these

threads in position. This is the principle used on modern guns, with the exception of some quick-firers which are fitted with a breech-closing mechanism that slides across the back of the gun. In the modern anti-aircraft quick-firing gun, the force of the recoil is used to perform the work of opening the gun, extracting the empty cartridge case, reloading and closing the breech for the next shot.

To return to the gun-barrel itself; in the middle of the last century, Lord Armstrong constructed a gun on principles which were to revolutionize artillery. Briefly, this gun obtained great strength by utilizing wrought-iron tubes shrunk over a steel "liner". The gun was, in other words, "built up" instead of being cast or wrought in a single piece. Very rapid development in a number of countries followed. Whitworth produced a gun which was built up, but instead of the tubes being shrunk on, they were forced into position by hydraulic pressure. Steel quickly began to replace wrought-iron for the covering tubes or hoops and was in common use by 1885.

At this time another important development took place, steel wire being wound round the inner tubes to give vastly greater strength. The wire is wound at varying tensions in successive layers. It does not contribute to the longitudinal strength of the gun, but makes it "elastic", taking up some of the great strain produced by the firing of a charge. Indeed, the somewhat complicated principles of modern gun construction can best be explained by saying that whereas the old cannon was a single piece of metal, taking the whole force of the explosion, the modern gun gets its

strength by absorbing some of the forces produced owing to the "tension" of the different parts. There was a definite limit to the strength obtainable with the old method of construction because as the gun was made thicker, so the strength contributed by the outside diminished. The modern gun makes use of the greater elasticity of steel in a state of compression.

The method by which a modern gun is now constructed is roughly as follows. Naturally the number of tubes and so on varies considerably with the type of gun. Inside is a "liner" which carries the grooves giving the projectile its spin. The wear and tear on this resulting from the passage of projectiles is considerable and therefore for the sake of economy the gun is made so that the liner can be removed and replaced when it is worn out. The liner is thicker towards the breech end, but the interior measurements are the same all through. In the case of quick-firing guns, notably those used for anti-aircraft firing, the liner is generally "loose", which means that there is a small clearance between it and the covering tube. When a shot is fired the liner expands and is held tightly against its covering which takes up the strain before the steel reaches its elastic limit. A keying device prevents the liner being turned round by the shell. The advantage of this is that the liner can be very quickly changed, a matter of some importance in guns which are expected to fire a considerable number of shots in a short time.

The liner is forced into the "A" tube by hydraulic pressure and if the gun is to be wire-wound this

process follows. The wire is actually narrow steel tape about one-twentieth of an inch thick and the tension is carefully controlled as it is wound round and round. The number of turns increases towards the breech, the quantity depending upon the size of the gun. A tremendous amount of wire is used in a big gun, in the case of a 15-inch naval gun over 180 miles of wire weighing 20 tons are required. Over this wire is shrunk the "B" jacket by making it with an internal diameter a little smaller than the exterior of the wire-wound gun. It is placed over the inner part when hot so that it shrinks and compresses the inner part as it cools. There then follows the rifling of the gun with special machines which cut a number of grooves at a time.

This account has for simplicity omitted mention of the fitting of "collars", end frame, breech ring, or the breech bush; it may not adequately convey an idea of the great skill and accuracy required. The building of a modern gun is indeed one of the major feats of engineering with every factor, from the quality of the steel to the exact temperature of shrinkage, absolutely controlled. Any failure would mean not only an inefficient gun but possibly a serious accident, and the rarity of gun accidents due to faulty materials or construction is testimony to the skill of those engaged in their manufacture. This is all the more remarkable when it is considered that some of the small guns, such as the 3.7 anti-aircraft, are "mass-produced". The big naval guns are made individually, it would be impossible to deal with the 100-ton ingot of cast steel by ordinary mass-production methods.

The steel used for guns is most carefully prepared, usually by the open hearth process, and tested at every stage for its chemical or physical properties. Test pieces of steel are subjected to breaking and bending tests. When the ingot has been forged, it is "oil hardened" and then tempered under carefully controlled conditions. Every inch of the steel wire is also tested.

One of the problems that became considerable with the increasing power of guns and particularly with the introduction of cordite, was that of the recoil. For more than two centuries, guns recoiled on wooden carriages fitted with wooden wheels. When the gun fired, it ran backwards until the recoil was absorbed, when it was pulled forward again by the gunners using blocks and tackles. This was not only clumsy, but unsatisfactory, when more powerful charges produced a greater recoil. The first important device for absorbing recoil consisted of a series of plates which pressed against the carriage when it was running backward, but lay down when it was running forward. Then followed devices in which the recoil was reduced by a piston working in cylinders containing liquid attached to the mounting. In the case of modern quick-firing anti-aircraft guns, the force of the recoil is utilized, working through compressed air, for bringing the gun to rest, restoring it to its firing position and ejecting the spent cartridge.

The modern big naval gun is carried in a cradle or a carriage and slide. The piston is attached to the gun and the cylinder containing liquid is attached to the cradle or to the slide. The effect of firing is to force

some of the liquid through the piston, taking up the recoil. The great power of these recoil-absorbers is illustrated by the fact that a big gun weighing over 100 tons will only travel backwards three feet before being brought up. To restore the gun to its firing position there is an arrangement by which the recoil either compresses air or winds a spring, the energy thus stored being utilized to bring the gun forward. In field guns, the arrangement for taking up the recoil is generally that of a cylinder held rigid and locked with the carriage to the ground.

For many years the method of firing a cannon was very similar to that of the musket, that is a small amount of powder was fired outside the gun, the flame being carried to the propellant charge through a hole. With the invention of detonators, it became possible to fire by percussion and this was further simplified with the introduction of breech-loading. In the case of quick-firing guns the propelling charge is fired by striking a cap contained in soft metal at the base of the metal container. For larger guns a tube is inserted and the initial firing is either electrical or by percussion.

The aiming or "laying" of artillery is much more complicated than that of small-arms, for the target is rarely visible. Laying is nearly always indirect, that is to say, the guns are not sighted on the target but on some observed object, the necessary deviation corrections being made. In aiming guns at sea, special problems arise, for the target is nearly always moving and the gun itself is moving with the ship on which it is mounted. For a single gun mounted on, say, an armed

merchantman, the method of sighting and firing is not unlike that used on land. The range is obtained, the direction determined and allowance made for the speed at which the target is moving, together with the speed of the wind. The gunner is able to see the splash of his shell and thus correct his aim.

But with a battleship in a general engagement, this method is impossible, and guns are controlled from a central station, generally somewhere fairly high in the ship so that a clear view can be obtained. The controlling officer has not only to give the gun-layer his range, but the rate at which that range is changing, so that he can alter his sights accordingly. The calculation of the deflection calls for some nice problems in allowances for the barometric pressure and temperature as well as the wind. The difficulties of hitting the target at ranges over 10 miles are very considerable, for not only is "spotting" difficult, but also the shells travel to a great height where the wind may be quite different from surface conditions, and every movement of the ship has a more pronounced effect on the shells as they leave the gun.

The instruments used for control are complicated and, in many cases, secret, but it may be said that such figures as the range, rate of change, deflection and other factors are passed from the central station to the gun turrets by instruments; in addition, speaking-tubes and special types of telephone are used. The transmitting room itself is a maze of instruments for making the necessary intricate calculations, those for calculating the rate of change in the range being particu-

larly ingenious. In the British navy a "master director" which is, in effect, a gun that does not fire, is used to lay all the guns. This director is laid and its motions are transmitted electrically to the guns which have simply to follow its lead. There is an arrangement so that the man beside the director can electrically fire all guns simultaneously, the moment of firing being hardly less important with moving targets than the correct elevation and deflection.

The science which deals with the movements of projectiles and is really the basic feature of all these inventions, is called ballistics. It is a branch of physics and like so much physics seems to the layman to be made up of a number of complicated equations. I will not attempt to explain the mathematics of it in a few paragraphs, but will deal instead with some of its problems and discoveries. With any projectile there are two separate sets of conditions to study, those inside the gun, before the projectile becomes free, and those during its flight through the air. During the first stage the projectile is under pressure from the explosive charge gases. During the second part it is a body travelling forward in air under its own momentum.

From the moment a cordite charge is fired to the instant when a shell or bullet leaves the muzzle of the gun, the time is, perhaps, two or three-hundredths of a second. But a great number of very complicated events have taken place in that short time. The burning cordite has generated gases which have eventually reached such a pressure that they start to turn the shell in its driving band, sending it forward.

The pressure increases until all the cordite is burned, when it continues under the expansion of the gases, although the acceleration is reduced. The muzzle velocity of the shell depends on many different factors, from the weight of the charge burned to the weight of the projectile, and from the work lost by friction of the driving band to the heat lost through conduction.

Given a few constants for a particular explosive which can be measured by special apparatus designed for the purpose, the ballistics expert can work out the muzzle velocity under any given conditions. Obviously, the ideal would be to secure a high pressure through the projectile's journey through the barrel, this would give the maximum muzzle velocity without increasing the maximum pressure. Explosives experts have worked hard at this problem, the solution of which would greatly increase range without calling for longer guns. The reason why a long-range gun is long, by the way, is simply so that the pressure can be applied to the shell for a longer period; in a short barrel the shell would be out before the pressure had reached its maximum.

Once in the air, the shell spins at a considerable rate, the gyroscopic effect keeping its "nose down" and correcting in some degree its desire to move away from a straight line. Nevertheless, every projectile does, apart from any wind, "drift" a certain amount. To determine the "drag" on a projectile due to the resistance of the air, ballistic experts use a chronograph which measures the time the projectile passes given points. These effects are calculated and provide

the constants which are used in calculating the laying of a gun.

The most remarkable piece of artillery ever made up to that time was probably "Big Bertha", the gun that was used by the Germans in 1918 to shell Paris from a distance of over 76 miles. The shell, which weighed 264 lbs., must have travelled to a height of over 20 miles in the course of its flight, and accurate aiming would require calculation of the effect of its passage through the partial stratosphere. This gun was a technical masterpiece, but of little practical value. It caused a number of deaths and a certain amount of panic at first, but the wear and tear was so tremendous that the number of shells which could be fired was very limited. Moreover, any definite aiming was extremely difficult owing to the unknown conditions of the air through which the projectile had to pass. The Germans took some trouble to destroy the secrets of the gun, but it is doubtful whether such weapons would be of much real use. Their weight, over 140 tons, made them very immobile and therefore susceptible to attack from the air. It may be that, if it is desired, to carry a charge of some 264 lbs. of explosive for 76 miles, an aeroplane will do it more surely and certainly much more cheaply. This gun will probably go down in history as an interesting technical freak, although similar experiments may become more practical with increasing knowledge of explosives.

Gun design has advanced rapidly during the last few years. The United States of America have now a weapon of 155 mm., nearly 6 ins. calibre, which fires $14\frac{3}{4}$ miles, is mobile, and is mounted on a carriage with

a speed of about 12 miles per hour. This by no means represents the ultimate development of modern artillery. The gun of the future will undoubtedly cause the men and women of those days to class our own efforts with bows and arrows or the blunderbuss.

CHAPTER V

CONCRETE

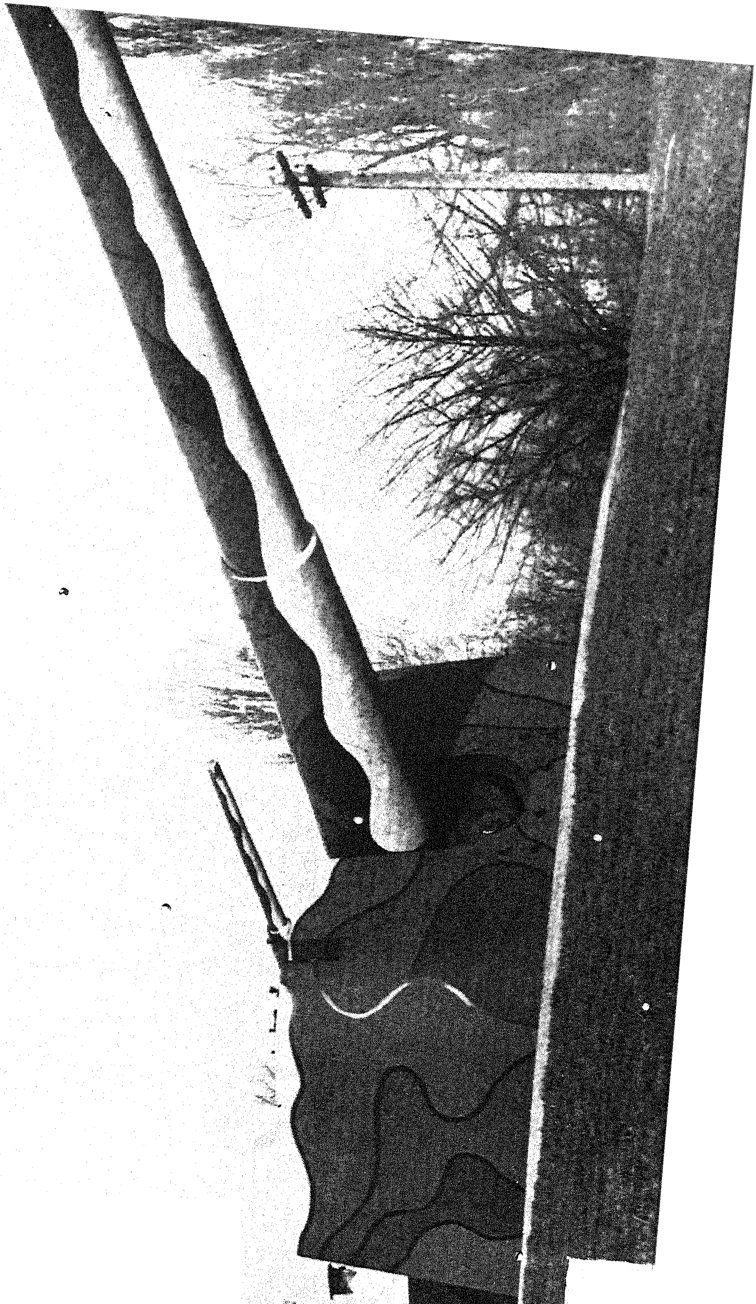
CONCRETE PLAYS such an important part in modern warfare that it might almost be called a defensive weapon. Along every frontier of Europe thousands of tons of concrete have been mixed night and day for months in the building of the greatest chains of fortifications the world has ever known. In all the great cities in Europe, concrete has played a major part in preparation of air raid shelters. It is almost the only convenient building material that is of sufficient strength to withstand the tremendous force of the explosion of a modern bomb or shell. From a military point of view it has the great advantage that it enables permanent fortifications to be prepared in as little as 48 hours.

What is concrete? Just man-made rock. Rocks are hard to cut to shape and must be cemented together. They are also of uneven strength and, of course, the harder the rock the more difficult it is to "work". The ancients built their castles of granite or other strong stone. We could build our modern air raid shelters of the same material and they would, no doubt, be quite effective, if less flexible after re-inforcement. But it

would involve tremendous expense and a vast amount of labour. How much better to grind up the rocks and remake them into something even harder, on the spot. That, in effect, is what we do with concrete.

Cement of different kinds had been used for thousands of years, but until the nineteenth century it generally contained a great deal of lime and was not very strong. Then the scientist Joseph Aspdin discovered that by heating together clay and limestone, while grinding the resulting substance very finely, a substance was formed which, with water, produced a cement far exceeding in hardness any yet known. The invention of this powder was destined to change war hardly less than the invention of another grey powder had accomplished five centuries before. Concrete, made by mixing this powder with water, sand and small stones, opened the way to the rapid construction of fortifications which could withstand the blast of high explosive. In turn, the power of high explosive was increased to smash the concrete and again the concrete was strengthened by the incorporation of steel bars. The strength of ferro-concrete will be known to anyone who has seen a "pill-box" which has received a direct hit from a large calibre shell. The fortification may be broken, but it is not blown to pieces. The twisted bars of steel still hold great blocks of concrete together.

Most people in these days have some first-hand experience of concrete, for widely as it is used for military and defensive purposes, it is even more used for constructing a thousand things from "crazy paving"



ntry Mortar

stones in the garden to roads and buildings. But most of us know little more about it than that cement is a fine grey powder brought in strong paper bags. If you pinch a little between your fingers you will appreciate some of the fineness of the powder, but you may not realize that the particles are so small that they would pass through a sieve with 40,000 holes to the square inch. This mesh is closer than a piece of ordinary silk. Water will not pass such a sieve because of the surface tension. The ideal would be, no doubt, to have cement ground so fine that each particle contained only a few molecules of the chemical constituents. This is not practicable, but the manufacturer gets as near to it as possible in order that when the mixture is made the chemical or growing action shall take place as evenly and widely as possible.

Portland cement does not, as its name suggests, necessarily come from Portland. The name was originally given to the substance because it closely resembled in colour stone quarried at Portland. It is not a natural product, but the result of a chemical action brought about by great heat. The raw materials are clay and limestone. The clays provide the silicon and aluminium while the limestone supplies the calcium. The compounds formed are exceedingly complicated. Not for many years after Portland cement had come into common use was its chemical constituency understood and even to-day not all the complicated reactions which take place are known. But the scientific study of cement has added greatly to its value and nowadays compounds of certain other elements, such as chromium or manganese, are sometimes deliberately

added to produce cement suitable for making concrete for use in particular conditions; for example, when it has to be submerged in sea-water.

The clays and limestones required for cement are dug out in large quantities. About two tons of raw material are required for every ton of the finished product. The first stage consists in grinding the lumps to small fragments, first by machines which seem to "chew" the rocks with little more difficulty than we chew an apple and then by drums in which there are a number of large steel balls. The fairly fine powder resulting is subjected to great heat in a kiln, the various chemicals in the minerals being fused. It is interesting to note, by the way, that the cost of heating is greater than the cost of the raw material and that each ton of cement represents the combustion of half a ton of coal. Many chemical changes take place as the white-hot kiln rotates. The result is a greyish clinker which is allowed to cool and passed to mills where it is pulverized once more to the fine powder we know. A great part of the manufacturing process is now carried out automatically and the final powder is packed by falling from a chute into waiting bags which stand on scales.

Although manufacture is carried out on a very large scale, every step is as carefully controlled as if a few ounces were being prepared in the laboratory. The chemical constituents of the raw materials must obviously vary, but the chemist exercises such control and the mixing is carried out so thoroughly, that thousands of bags of concrete contain a powder which is chemically exactly the same. For various purposes

additional substances are added during manufacture. For instance, a "dispersing agent" is added which ensures that the small particles of concrete remain separate and do not stick together to prevent proper mixing. The amount added may not be more than one part in 250,000 of cement, but its presence is exceedingly important. The speed at which concrete sets can also be regulated by additions to the cement. The commonest substance used to slow down the hardening process is gypsum and as little as one part in a hundred is sufficient. To secure more rapid setting other chemicals are used.

Concrete consists of a mixture of sand, small stones and cement. The cement with the sand forms a mortar which as a result of chemical actions in which heat is released, sets hard and binds together the small stones. The exact proportions of cement, water, sand and stones are important, affecting the strength of the finished product. The size of the stones affects the mixture and it will readily be seen that since the cement and sand simply fill up the gaps between, the larger the stones the less, in proportion, the cement required. In the past, concrete has often been made by roughly throwing together something like the desired proportion of constituents, but for important work, such as fortifications, where many lives may depend upon the strength of the finished product, the mixture is carefully weighed. Engineers can calculate the strength of the resulting concrete with the same accuracy as they can the strength of steel, cast iron or other materials.

In setting, concrete gives off heat and for large masses

of concrete this must be carried away to prevent cracking. In the construction of the Boulder Dam, which called for 7,000,000 tons of concrete, special refrigerating apparatus was installed, and X-ray examinations made during erection of the main blocks with their supports. Ferro-concrete was the invention of the Frenchman Joseph Monier about sixty years ago. It consists essentially of using steel bars, wires and mesh to act as a universal binding for a large mass of concrete and enables it to bear compressive and tensile stresses which would otherwise produce cracking. The use of metal enables concrete to be moulded with great strength into almost any desired shape.

One of the most interesting experiments with concrete was the production of concrete ships as the result of a shortage of raw materials during the Great War. The largest of the concrete vessels was one of over 1,000 tons, although the majority were barges and steam tugs. Curious as it may seem, the relative weight of the hull was less than that of a wooden vessel, although greater than that of a steel ship. The real disadvantage discovered was that concrete would not "give" like wood or steel when the vessel was bumped, as against the side of a dock; but it was found that quite a thin hull could be made perfectly watertight. A rich mixture was used, of course, and the hull given its longitudinal strength by means of steel bars. It is unlikely that concrete ships will ever become widely used, except under special circumstances, for steel provides an equally strong and in many ways a preferable material.

One of the great advantages of concrete construction for defensive purposes is that it is non-inflammable and, for practical purposes, impervious to heat. Very great heat may result in cracking, but experience has shown that even the larger incendiary bombs up to 60 lbs. which are unquenchable by normal methods do not destroy buildings of concrete and steel construction.

In considering defence against aerial bombs, two types of explosion have to be considered. The effect of a bomb which explodes on contact is often downwards and sideways along the ground. Anything not directly beneath it below ground-level is fairly well protected. The damage is done, not so much by splinters, as by the tremendous explosion wave. Recent research has shown that this causes buildings to collapse because it is followed almost immediately by a wave of "negative pressure" and the effect is very much the same as that of a tornado, a brick building being actually "sucked down". The blast lasts less than 1-1000th of a second, the noise alone being very damaging. With delayed fuses a bomb penetrates some distance before exploding and the shock is such that complete immunity to direct hits by the largest bombs would call for concrete of immense, if not impractical, thickness.

This difficulty has been overcome to some extent in the construction of the strongest shelters by building a series of layers designed to take up the shock and to place the minimum pressure on the concrete. In a deep shelter there would, according to the latest practice, probably be a layer of "small" material on

top to burst the bomb. This acts as a "cushion" for the bomb or shell, taking up a large part of the explosive force. If the bomb goes right through this layer before it explodes, instead of solid earth forcing the explosion downwards towards the shelter, there is a yielding layer which easily gives way and allows the shock wave to reach the air. Underneath this is a layer of soft earth designed still further to take up shock, and it is only under this final covering that there is the layer of concrete covering the actual refuge. It has been realized that double walls have a cushioning effect on an explosive wave and therefore, while a single concrete wall a foot thick is stronger than two walls each of six inches close together, for protection against explosion the two walls are better, the first acting as a cushion and greatly reducing the blow on the second structure.

The effect of blast, or the compression wave, is reduced very quickly with distance. To be exact, the force is commonly reduced as the cube of the distance. Therefore, if the chances of a direct hit are small, protection against bombing can be afforded with a comparatively light shelter. This is designed to give protection against blast, except where a large bomb explodes within a few yards, against splinters or falling débris. The ordinary light shelter does not give protection from a direct hit.

Most people think in terms of bombs and shells striking defences from above and passing through the roof. In actual fact because bombs and shells fall in a curve, a large number of hits may be made on the side of buildings and for any structure above-ground

protection on the side is hardly less important than protection above. As far as blast and flying débris are concerned the protection on the side is all-important; it is for this reason that small shelters are banked up with earth which absorbs the shock wave and reduces the speed of flying splinters before they reach the concrete.

To guard against the damage of a bomb striking obliquely, concrete shelters of special design have been evolved on the Continent. These are conical in shape, very much thicker at the base than at the top. A bomb hitting one of these is deflected sideways so that the maximum force of the explosion is directed towards the base which is best able to withstand the blow.

The principle military use of concrete is in the construction of fortifications. Wars have involved sieges since the earliest times and a variety of ingenious pieces of apparatus, called engines, from the battering-ram to the "approach tortoise" were evolved with the one object of breaching the fortifications and allowing the attackers to scale. Each new device for attack has been countered by one of defence, for instance, the "approach tortoise" which was a covering to give shelter to attackers engaged in filling up a ditch, was countered with grapnels dropped on the roof to tear it up. Very few fortified places have proved themselves impregnable, although some, like Port Arthur in the Russo-Japanese War, held out for a surprising length of time.

The coming of high explosives or long-range artillery called for a revision of the very complicated technique

of fortification and it seemed for a time as if the attackers definitely had the upper hand. The invention of ferro-concrete which made possible the construction of fortifications able to withstand the heaviest bombardment balanced matters, but in the early stages of the Great War the Belgian forts were battered into subjection in a surprisingly short time by the 17-inch howitzers which the Germans had constructed specially for the purpose.

During recent years the idea of the single fort has given place to the fortified line, for a variety of reasons which will be obvious. The pre-war idea was that of a series of forts lightly linked together by trenches. To-day, the great fortifications of Europe consist of continuous fortified lines, prepared with great elaboration, the greater part of the fortification being underground. Millions of tons of concrete have been poured deep into the earth along the French, German and Russian frontiers, the only part of the fortifications above-ground being the "pill-boxes" containing machine-guns or artillery. Approaches, the magazines, sleeping quarters and rest-rooms for the soldiers, are all constructed of concrete buried deep in the ground. The whole system is electrically lit from well-protected dynamos, air-conditioned and proofed against gas. Photographs and films have made the Maginot Line fairly familiar to most people. It would have been quite impossible to construct, of course, without concrete engineering. The fortifications are accompanied by tank mines and traps, iron rails placed at an angle in concrete so that they would strip the tracks from any ordinary tank attempting to pass them and

barbed-wire entanglements. Their builders are convinced that these new forts are impregnable; that has been the fond belief of fortress builders since the earliest times. Whether, in fact, concrete has at last mastered high explosive remains to be discovered in practice.

The builders of a fortress are always at a disadvantage for they have, as it were, to lay their hands on the table, while the attackers have ample time to devise special means of overcoming obstacles of which the strength and nature are exactly known. If a fort is finished to-day, an attacker may have three or four years to plan and build special guns or other weapons for the attack. Already troops are being trained in methods of capturing the apparently impregnable "pill-boxes" fed with soldiers and munitions from below the ground. If it could be shown that fifty or a hundred million pounds spent on concrete fortifications underground would render a line impregnable, it would seem that the boundaries of Europe could be settled once and for all. But the whole history of warfare suggests that there is no such thing as an impregnable fort, only a fort which cannot be taken for a given length of time.

It is far from impossible that the future line of defence will be no less than a specially excavated underground city to which trains can be run from all surrounding districts and from which aeroplanes can rise as the one means of escape. Power travelling machines will help armies to "dig themselves in" so that positions may be consolidated within a few hours, soldiers will exist under the earth while outside

no living being could last more than a few seconds. Trench warfare has only begun. Aerial attack has not altered the fact that land or money are the ultimate objects of nearly every war.

CHAPTER VI

OPTICS

MODERN WAR uses every science and optics, the science of light transmission, is one of the most important in a number of fields. Optical instruments are not at present actual weapons, but more generally the accompaniment of practically every form of defence and attack. Without them, large guns and submarines would be impossible and every other form of warfare would be impossibly handicapped.

One of the most widely used instruments is the range-finder, a device which determines the distance away of an object without direction measurement of the intervening space. The military and naval range-finder is in principle exactly the same as that which you use on your camera for determining the distance of an object so that it may be in exact focus, but there is this difference that whereas your camera needs to deal only with objects less than perhaps twelve yards away, for military purposes a range-finder may have to measure up to twenty miles.

There are a number of different kinds of range-finders, but nearly all are based on the same mathematical principle, the completion of a triangle of which the

base is known by measuring the angles at the base, or as our trigonometry calls it, the "solution" of the triangle. In a range-finder the base of known length is the range-finder itself and to determine the distance of the target on which guns are to be fired, the angles at the base of the imaginary triangle, formed by drawing imaginary lines from the target to the two ends of the base, are measured.

Our own eyes are a moderately efficient form of range-finder working on this principle. The base, in this case, is the distance of a few inches between the two eyes, and the measurement of the angle is performed unconsciously by our brains when we glance at an object. For this reason it is always more difficult for a man with only one eye to judge distances accurately; he has single, instead of stereoscopic, vision. Fortunately, we also judge the distance of objects, roughly, by their apparent size of habit-perspective, otherwise the man with one eye would be quite unable to say whether an object was five or fifty yards distant.

As it is, the human range-finder is not very accurate. It is good enough, with experience, for judging distances for most rifle fire since the modern rifle, as I have explained, has a comparatively flat trajectory. But for artillery where the projectile travels in a curve and "drops" onto its target, range is all-important. An error in estimation of a few yards may result in the target being missed altogether. With a flat trajectory, such an error would not matter at all and with a comparatively flat trajectory a much larger error is permissable. Range-finders are particularly important to

naval and anti-aircraft artillery. They may be helpful, but are not essential to artillery on land where guns may be laid with the help of maps and "spotting" of the target either from an observation post or an aeroplane.

For reasons of portability and convenience, most range-finders must be of limited length, and the fact that the base of the imaginary triangle to be measured is very small compared with the length of its sides, means that the angles made by these sides must be measured with great accuracy. In practice the man using a range-finder does not have to measure any angles, this task being performed automatically as he manipulates the instrument. His work is limited to reading figures on a dial. It will readily be seen that, other things being equal, the longer the range-finder the greater the accuracy; the range-finders in use on warships to-day vary from four or five feet to about forty feet in length according to the maximum ranges to be measured and other conditions.

To increase the accuracy of a range-finder by reducing the human error, the optical arrangements are such that in fact only one angle is measured, the other angle always being a right angle. At each end of the range-finder, which is basically a hollow tube with a hole in the middle for the observer, are pairs of mirrors or a prism. Light coming from the target is reflected along the tube from each end through a telescope onto prisms in the centre, so arranged that they turn the light into the eye-piece, which may be either single or double according to the type of range-finder.

In the range-finder with a double eye-piece or stereo-

scopic type, the observer sees a different picture of the target in each eye. It is just as if a stereoscopic camera had taken a double picture, each of which appeared at first glance to be a duplicate of the other, but in fact differed very slightly because it was taken at a slightly different angle. Each eye-piece has a permanent mark and these two marks are seen as one. To take the range the operator manipulates the range-finder until this mark which he sees is apparently the same distance away as the target, when the range can be read off. The great disadvantage of this type of range-finder is that so much depends upon the skill of the user in judging when the mark and the target appear equally distant. In the hands of a skilled soldier it is probably as accurate as any type, but the ability to judge when two objects are equidistant varies considerably, even with the same individual, according to his health and other conditions.

In what is called the coincident or single eyepiece type of range-finder, two images are seen, one from the right hand end of the finder and the other from the left. One beam of light is always travelling at right angles to the prism refracting into the eyepiece, this is the light coming at an angle of 90 degrees. The angle of the other beam of light depends, of course, upon the distance of the object and this shows as a separate picture. The instrument is manipulated to bring the two separate images together on a very fine line when the range can be read off. The optical apparatus can be arranged in a variety of ways, the commonest of which in the military range-finder is to allow the upper ray-image to be inverted.

If you were looking at a tower, for instance, you would see the tower at the bottom in the ordinary way, but there would be another tower upside-down apparently in the sky. As you moved the controls, which alter the angle of the optical apparatus inside the tube, the two images would move together until at last the points of the spires exactly met. You would then "have the range" which could be read off either on a dial appearing at the side of the image or at some other part of the range-finder.

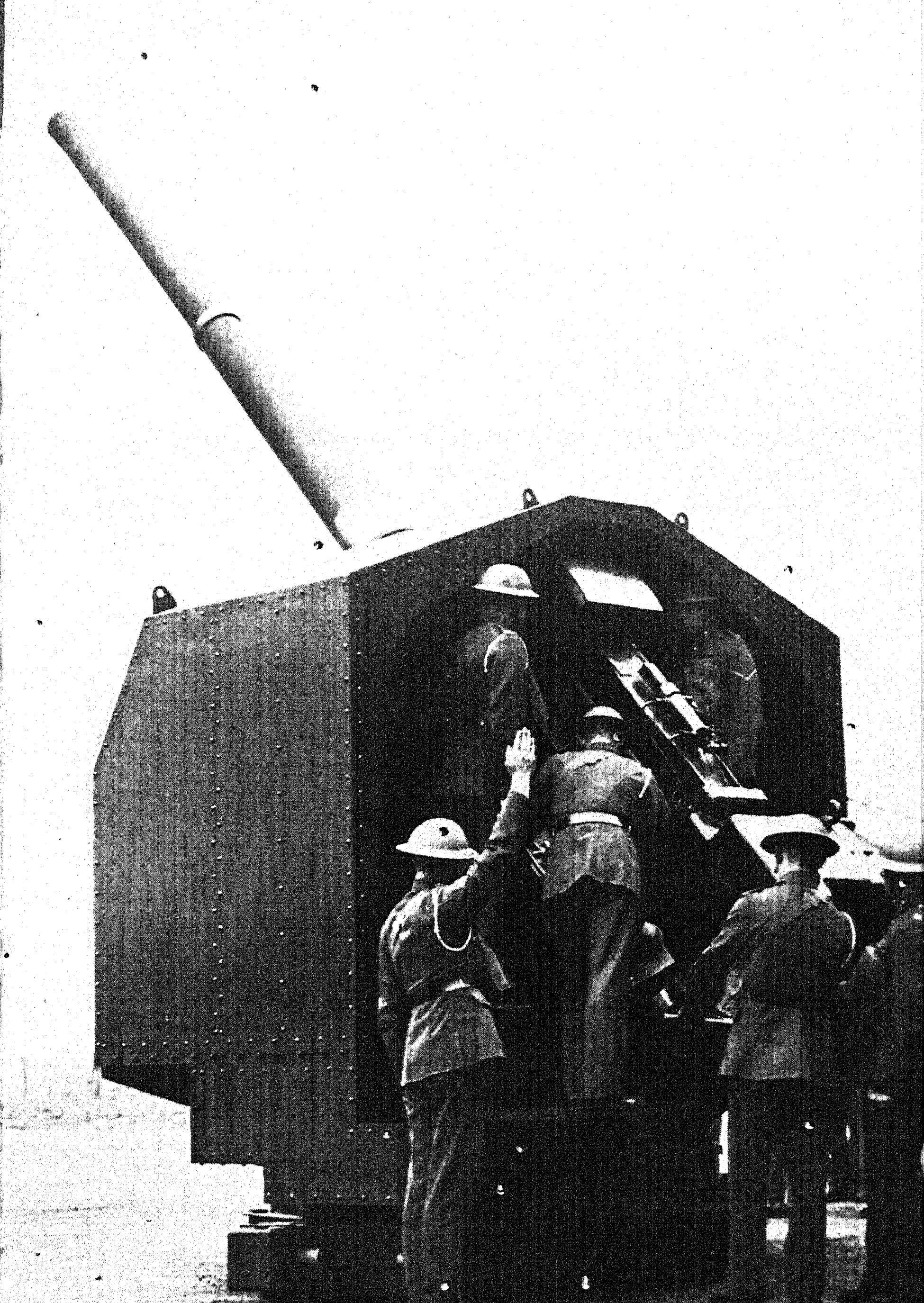
Although these range-finders have probably been brought as near perfection as human ingenuity and optical science can make possible, there is still a margin of error, which depends upon the relationship between the length of the finder and the range being measured. For this reason longer range-finders are used for long ranges. To reduce the possible technical error to about 100 yards at a range of 20 miles, a range-finder 100 feet long would be required. At ranges up to 10 miles, a 9-ft. range-finder is sufficient.

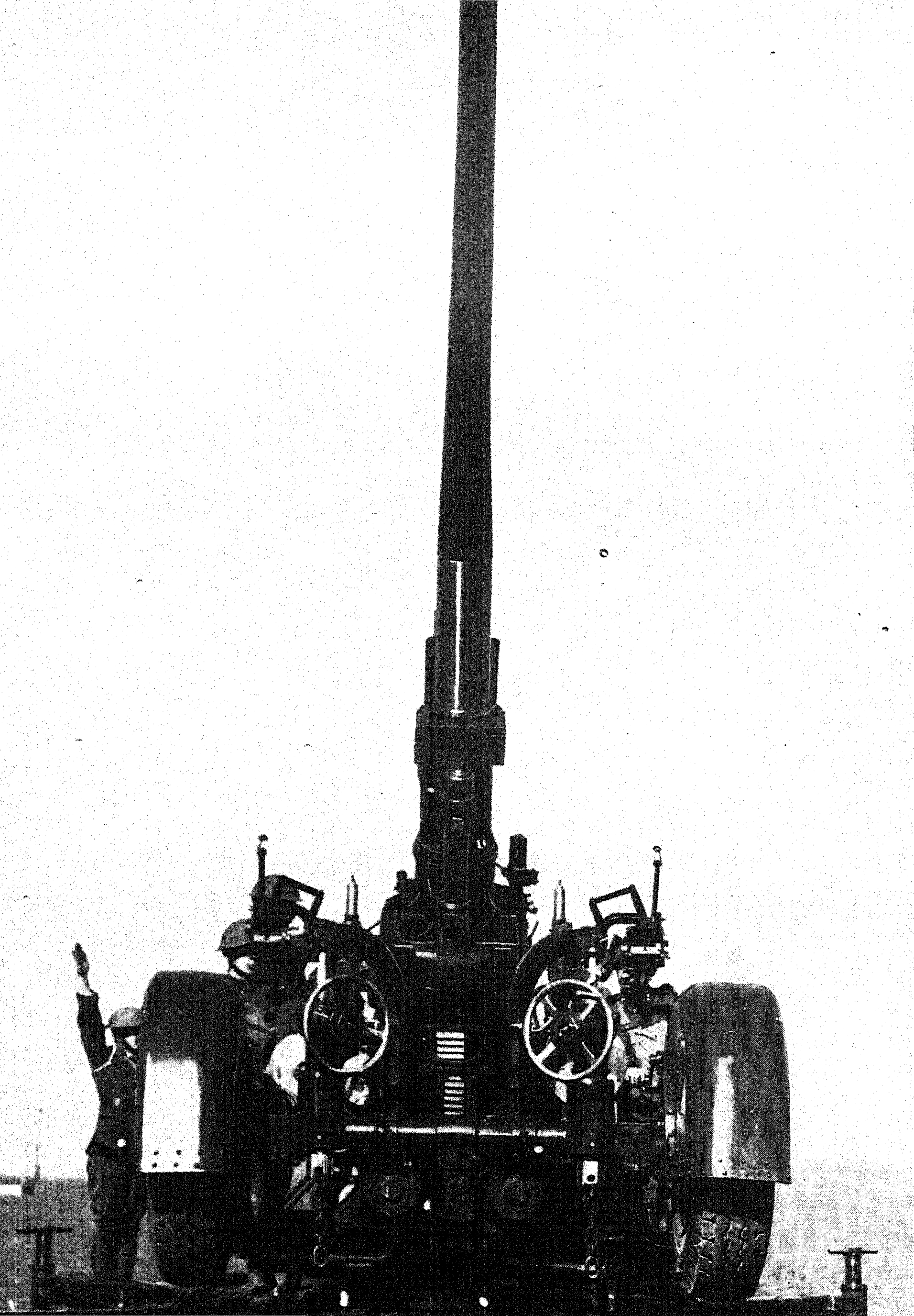
A range-finder is a delicate piece of apparatus and it may be that this simple description may not give an adequate impression of its complexity. Where you are dealing with the very narrow angles of a beam of light being refracted by a prism, extreme accuracy in manufacture is required. Britain has been foremost in the manufacture of range-finders for some years and probably leads in this all-important field to-day. Because of the accuracy of their first salvoes at the Battle of Jutland, the Germans acquired a high reputation for their range-finders, but more careful consideration of the battle has led experts to conclude

that this accuracy was not real and that the German range-finders were no better than those made in England.

In certain conditions on shore, another system of range-finding is possible, making use of two separate observation points. Telescopes are trained on the target and the angle formed noted and telephoned to the gun position where the necessary calculations are made, generally with electrical instruments which perform the task in a hundredth part of the time necessary for a human being. This system of range-finding called "the horizontal base" system has the advantage of great accuracy owing to the very long base used. It has several disadvantages, including the difficulty, except in prepared positions, of arranging telephonic communication, and for the most part it is used by coastal defence guns. This system also employs electrically-operated dials which reproduce the movements of gun-laying dials at each end of the base, automatically.

A third system of range-finding depends on measuring the angle at which a telescope at a definite height has to be depressed to be focused on a target at "sea level". The base of the triangle to be solved in this case is the perpendicular of the cliff or prominence on which the range-finder is placed and this, naturally, makes a right-angle with the sea level. In actual practice the measurement of the angle is carried out by fixing the telescope so that it can be brought to bear on an object anywhere between certain limited ranges by sliding it backwards and forwards on a bar which is graduated in marks representing the ranges. These instruments call for certain corrections such as the





height of the tide at the time and the curvature of the earth, but these details can be compensated automatically. The base is considerably longer than in the case of the first type of range-finders and considerable accuracy can be obtained, but the application, except for coastal defence, is somewhat limited.

In range-finding for anti-aircraft guns, slightly different principles are used, for the matter is rather more complicated. An anti-aircraft gun works to the particular height which remains fairly constant, and the angle and the instruments used are therefore height-finders rather than range-finders. An equation gives a constant relationship between the height, range and elevation, and a height-finder may therefore be a range-finder of the first type described, with a device for working out the rather complicated equation. This is accomplished by an exceedingly accurately made cam and gears. A re-arrangement of the optical apparatus in a range-finder invented in 1916 enables the observations and adjustments to be made directly in terms of height.

The principle of observation from a "long base" or two different points has also been adapted to height-finding. The mathematics of this type of height-finder involve a fair knowledge of trigonometry, but in practice they are performed on part of the range-finder which has carefully drawn curves on a plate so that adjustment to the observed angle gives the height. However, this type is not often used for spotting aeroplanes, chiefly because speed is all-important.

Anti-aircraft gunnery involves a number of problems

which do not worry the gunlayer working on other targets. The target is moving rapidly, possibly at varying heights. It can change direction in a few seconds and move in three dimensions. The speed of the wind is a further point of considerable importance since it can drift a shell some distance, and finally, as the shell will take some seconds to reach the point at which it is aimed, it is useless to aim directly at an aeroplane. A gun must be aimed so that the shell will be at the point where the aeroplane will be after the elapse of the time taken to reach the target. An aeroplane flying at 180 m.p.h. moves 268 feet a second, so that when the aeroplane is at a considerable height it may be necessary to aim many yards in front.

All these factors can be calculated and the point at which the gun should be aimed decided, but a human being, even with tables to help him, is likely to take so long over the calculation that by the time he can give the gunners the elevation and fuse setting, the aeroplane will have changed course. The predictor is a combination of optical instruments and a mechanical mathematician. It takes into account all the factors mentioned, and provided the observers keep turning the controls "on" the image of the target, the correct angle and fuse setting can be read off. They may be transmitted electrically to the guns. This wonderful instrument, in which complex equations are solved continuously in one-hundredth the time that would be required by a human mathematician, has added enormously to the accuracy of anti-aircraft guns and largely explains the greatly improved standards of gunnery in recent

years. During the Great War airmen did not take anti-aircraft guns very seriously, knowing that being hit at any great height was largely a matter of luck. To-day it is very different.

Another optical instrument of importance in war is the periscope. This is used not only for submarines, where it is essential, but also for safe observation on land. The periscope can be raised above fortifications when it would be quite unsafe for a man to raise his head. The principle of the periscope is exceedingly simple. It consists essentially of an optical tube with a small opening at the top to admit light rays. These rays are reflected from a mirror set at an angle down the tube where they meet another mirror which reflects them out of the back of the tube into the observer's eyes so that he appears to see the object under observation. Such a simple periscope can be very easily constructed at home with two mirrors and a cardboard tube. Indeed, if the object to be observed is well-lighted, the tube can be dispensed with and a simple skeleton holding two mirrors at an angle proved quite popular for looking over the heads of the crowd at Coronation time.

Although the principle is the same, the practice is not quite so simple in a submarine periscope which must be at least thirty feet long. The construction of the tube itself calls for some care. A submarine travelling at even 8 knots when submerged subjects the periscope standing above it to considerable strain from water resistance. Therefore there is a limit to the diameter of the periscope. It is also important that the periscope should be small in order that it shall not make a con-

spicuous wake or be easily observed. At best a submarine periscope is, from the optical point of view, a compromise, but the balance of sacrifice between magnification, field of view and clarity has been obtained to a remarkable degree.

Instead of mirrors, prisms are used as reflecting surfaces. The light entering through a piece of ordinary glass which seals the tube and makes it watertight, is reflected downwards. It enters a series of lenses which are the equivalent of a telescope the wrong way round and then another series of lenses which form a telescope the right way round. This magnifies part of the image which is reflected into the eyepiece by another prism at the bottom of the telescope. There are, of course, devices for focusing the instrument which can be raised and lowered, for increasing the magnification at the expense of the field of view, for seeing the bearing of the object viewed and gauging its approximate distance. Periscopes used in observation posts and in trenches follow the lines of those used in submarines but because, as a rule, such great length is not required, the optical system can be simpler.

The searchlight is an optical instrument first developed for use by warships at night but now of supreme importance in anti-aircraft protection. The principle of a searchlight is that all the light from a bright source is so reflected that each ray travels in a direction parallel to the axis of the mirror. Of course the light does not travel in a truly parallel ray, for, apart from the impossibility of avoiding some dispersion, this would mean that only a spot as large as the searchlight

would be illuminated. The shape of the mirror required to reflect in this way is not hemispherical but parabolic and the making of it calls for fine optical work although machines have been devised for automatic production.

The source of light, filament or "arc", is placed at the focus of the mirror and the effect is immensely to "magnify" the light, since instead of being scattered, all the rays are concentrated within narrow limits. The filaments used are of very special type, the greatest step forward in the searchlight being made in 1915 when Sperry, the American inventor, devised a satisfactory means of cooling the source of light used. The result of his inventions was to make possible a searchlight with a total of some 1,500,000,000 candle power, a tremendous light that would be visible, but for the curvature of the earth, at a distance of 150 miles. Improvements have led to the production of searchlights of even greater intensity.

It will readily be seen that the control of a searchlight is not simple, for the smallest movement is magnified thousands of times and the movement of the actual light through a very small angle will send it through hundreds of yards at a distance of a few miles. Men using searchlights are expertly trained to "follow" an aeroplane even when it performs sudden changes of height and course in an endeavour to escape the beam.

It is sometimes asked why the beam of a searchlight does not travel onwards for ever instead of fading out. Light is a form of energy and thus exhausts itself by turning into other forms of energy. Theoretically,

searchlights should raise the temperature of the air, although the amount is so small that it can only be measured with delicate apparatus. It must also be remembered that the light has to perform a double journey, it has to travel to the aeroplane and then make the journey back as reflected light. Naturally, only a small portion of the light is reflected, particularly if the aeroplane is painted black, and a searchlight could be seen at more than double the distance at which it is effective for illuminating an object.

The searchlight has hitherto been a purely defensive or auxiliary weapon of which the purpose was simply to illuminate a target for guns. But with increase in power it might develop into a weapon of offence by blinding those upon whom it shines. Even as used at present, searchlights may have a devastating effect on pilots who, of course, are taught not to look down at them. An invention was put forward not long ago for switching searchlights on and off by means of a rotating shutter. The idea behind this was that the eyes of any person looking at the light would be unable to accommodate itself to the quick changes from light to darkness and would quickly be put out of action. It was stated that in experiments the person subjected to this light developed terrible pains and lost control of himself. This is possible, but it must be borne in mind that enemy airmen are not likely to be so obliging as to look directly down at the light designed to blind them. By fixing his eye on a distant star or some other point, the pilot would be naturally undisturbed by any except the most unusual searchlight.

In addition to these optical instruments described

there are many others used in modern warfare, from the telescopic rifle sight to the bomb sight and binoculars or telescopes. But these are only adaptions of inventions made for non-military purposes and do not therefore call for special explanation. It would be difficult to overestimate the importance of optical equipment in modern warfare, especially as ranges increase and movements become more rapid. As with so much else military equipment, the advantage is with the country that in normal times has a well-established optical industry. The making of optical instruments calls for a craftsmanship that can be gained only by experience, and nations which depend upon imported optical instruments are particularly handicapped in war-time when large supplies are suddenly required.

Various experiments in connection with the use of electrical and optical apparatus for the detection of aeroplanes by infra-red rays have been attended by considerable success. This really amounts to detection by heat and at the same time an apparatus has been designed which causes a searchlight with its gun to follow an aeroplane semi-automatically. Unfortunately the mechanism is somewhat liable to derangement; there is an example of it being thrown completely out of gear by a single fly.

Invention is solving most of these defence problems with surprising speed. Guns and lights that follow the movements of one master control, radio-optical apparatus that decides height from the earth by reflected waves, television, sea-sounding machines, "wireless" aeroplane and submarine detectors and even bombs

which may eventually be made to follow a light beam or a distinctive sound; all are developments of early sighting mechanisms which have been devised for use in any modern war.

CHAPTER VII

ACOUSTICS

THERE IS NO DOUBT that sound has played some part in warfare since the very beginning. The distant tramp of marching feet, the thud of horses' hoofs, and similar sounds, betrayed the position of moving bodies of troops. Man, very early, learned the trick of putting his ear to the ground to listen for distant foot-steps or for cavalry. Sound travels better in most solids and liquids than in air, if, therefore, the earth is used as a conductor, sounds can be heard from at greater distances. They are, of course, carried even more effectively by metals and an ear on a railway line can detect the movements of a railway train long before its sounds become audible through the air. It is not a practice to be recommended, however, for reasons of safety.

Gunfire added to the noise of battle, but no serious attempt seems to have been made to utilize it for scouting purposes, partly because there was generally no great material advantage to be gained by learning that guns were being fired in a certain direction and partly because the science of acoustics had not advanced to the point where mechanical aids to hearing were

available or when they could be used for electrical range-finding estimations.

The human ear is a singularly inadequate sound-detector for many purposes. It has a threshold of hearing that cannot compare with that of sensitive microphones. The threshold of hearing is the point at which sounds become so "weak" that they cannot be heard. Technically, the sound waves are not sufficiently strong to vibrate the drum. There are also comparatively small upper and lower limits to the pitch of sounds that can be heard. The human ear cannot detect sounds of a pitch lower than about 16 frequencies per second or above about 30,000 cycles. It is by no means perfect as a direction-finder. For sound detection as applied to military purposes, the ear needs mechanical or electrical assistance and in the course of the present century some remarkable pieces of apparatus have been devised for sound detection for various special uses.

The principles by which the direction from which a sound is coming, and therefore the position of whatever is making the sound, is discovered, are much the same as those used for range-finding by visual means. Observations are made at two or more points and these enable a course to be plotted. Actually, just as our two eyes enable us to find the range of anything at which we look, our two ears enable us to state approximately the direction from which a sound is coming, the width of the head acting as a base for the range-finder. The ears are able to detect the direction of sounds coming from one side or the other, but find it difficult to distinguish between sounds coming from behind or in

front. The analogy with light does not hold perfectly good, for in the case of the ears, it is probably the difference in a phase as appreciated by the two ears that gives a sense of direction. In the laboratory a sound can be made to appear to come from one side of the head or the other by an alteration in the phase. It is possible that a difference of intensity also contributes to our aural direction-finding senses.

Sound detection in war can conveniently be divided into different sections, according to the purpose for which it is required, although the methods overlap to a certain degree. There is the detection of sounds in the ground, the chief application of which is to follow an enemy engaged in driving a mine or sap. There is the detection of the direction and distance of gunfire, or sound ranging, which enables enemy batteries to be located, there is the detection of enemy submarines, either by the sounds of their propellers and engines or by the echo of specially generated sounds. There is also the detection of approaching enemy aircraft which enables long warning to be given while the approximate number, height or direction of raiders is passed to interceptor planes with their accompanying searchlights.

The device for the detection of tunnelling is exceedingly simple. Sound impulses in the ground are made to vibrate a diaphragm through a container of mercury. An actual instrument used in the Great War consisted of a hollow cylinder in the centre of which was a compartment closed by mica discs containing mercury. The compartments at each end containing air were connected to the ear by acoustic tubes like those of

a doctor's stethoscope. Vibrations in the ground on which the instrument was laid were thus turned into sound that could be appreciated by the ear. To find the direction of the sound, two of these instruments were used, one compartment of each being connected to each ear. By manipulation, the direction from which the sounds made by enemy tunnellers digging could be directly determined.

There are few branches of armaments in which secrets are better kept than those relating to sound-detector devices, but it may be stated that since the Great War many improvements incorporating the latest methods of electrical amplification have been made. In any future war in which mining operations play an important part, there is no doubt that enemy movements at a considerable distance could be detected with certainty and counter-measures taken at an early stage.

Sound-ranging is applied to the directional detection of explosive sounds, which calls for different methods from those used for the detection of more continuous sounds. When a gun is fired, three distinct sounds result. First of all there is the explosion wave caused by the expanding gases leaving the muzzle. This is the "boom" of the big gun as it is heard by someone a mile or more away. Then the shell itself as it travels through the air sets up sound waves. The effect of these varies with the position of the observer and the speed of the shell, which may well at times exceed that of sound, or nearly 1,100 feet per second. Thirdly there is the sound of the shell's explosion, quite different to that of the explosion in the gun owing to the faster

burning explosive used and to the fact that the sound can spread in all directions. The three sounds may be roughly described as a boom, whine and bang.

The variations in the sound of the shell itself can lead to some judgment of its position and direction. Experienced soldiers became adept at telling from the sound where it was going to land or of what calibre it was. Owing to the high velocity of shells, it was generally the type that you did not hear that was dangerous, in other words the sound reached you after the shell had landed and exploded. Men with very acute hearing were able to move about until they found the position at which shells changed their tune owing to their having reached the upper limit of their curved path. From this position, ballistic experts with the aid of a map were able to work out the approximate position of the battery firing the shells. I believe that the extremely sensitive ear of the great violinist Kreisler was once utilized for this purpose.

But this is not a sufficiently accurate method, and sound-ranging was generally carried out with a number of microphones placed at carefully measured points over a base of over two miles and perhaps three or four miles behind the lines. These microphones were connected with a central observing station and as the sound of a gun being fired reached each one, the fact was recorded electrically at the central station. The difference in time between the moments when the sound reached each station enabled a circle to be drawn, the centre of which was the point of origin of the sound, in other words the enemy gun. The mathematics involved are not very complicated, al-

though corrections have to be made for the temperature and wind, both of which affect the velocity of sound in air.

Simplicity and speed is essential in calculations of this kind, and the actual apparatus used was interesting. To eliminate other sounds, particularly that of the passing shell and ensure it was only the "boom" of the gun that was recorded, a special microphone sensitive only to low sounds was used. The changes in current in a platinum wire from the compression effect of the sound traced themselves photographically on a film at the recording station. This was automatically developed and delivered, showing six lines, one from each microphone, and the time in hundredths of a second. It was thus only necessary to look at the film to be able to write down the differences in time. To ensure that all six microphones recorded the same wave of sound, an observer in an advanced post telephoned warning of an approaching sound and the instruments were not switched on until this was received.

Sound travels well in water and with suitable instruments the engine and propeller noises of a boat can be detected at a considerable distance. Under-water explosions during the War were accurately measured at distances up to 60 miles with apparatus very similar to that used for sound-ranging guns. But for detecting the presence and position of a submarine, microphones at the bottom of the sea at carefully surveyed points cannot be relied upon, and other methods have to be used. A good deal of the confidence that is felt in British naval circles in the ability of

surface craft to deal with submarines is due to great improvements in undersea sound-detection and to radio. The submarine which has been a menace to every type of ship for thirty years because of its invisibility, can often be revealed acoustically. The details of the latest submarine detectors are closely guarded secrets and I cannot do more than indicate the principles upon which they can be based. I do not doubt that in future hostilities a day and night watch on the acoustical detectors would be kept and no submarine could approach within torpedo distance without being heard. Microphone noises focused for acoustic camouflage have also been suggested by several inventors.

A microphone mounted in the centre of a large diaphragm suspended under the surface acts as direction-finder because a sound is heard at a maximum when the diaphragm is broadside on to the source. As the diaphragm is turned, the sound gradually diminishes in strength until it is at a minimum when the diaphragm is "edgeways on" to the direction from which it is coming.

Double trumpets like those used for listening to aeroplane sounds can be used, the sound coming louder to one ear than to the other. As the trumpets are moved round there comes a point when the sound coming to each ear is exactly the same and at this moment of balance, a line drawn at right angles from the base of the two trumpets gives the direction of the sound. In practice at sea it is not convenient to move about receivers under water in this way and the "path" of the sound to the ear is varied instead.

Another method of submarine detection can be based upon the fact that sounds in water are echoed in exactly the same way as in air. A sound is produced under the water by an oscillator and the return of this sound detected by a microphone, or hydrophone as one should more strictly call it, perhaps, when applied in this manner. The interval of time that elapses between the emission of the sound and its return, multiplied by the velocity of sound in water at the known temperature, gives twice the distance the echoing object is away from the observer.

This device can be used in various ways. It can be used for simple detection. Sounds sent out laterally will not be reflected at all in the open sea. If their return is detected, it is obvious that there is some solid body reflecting them. This has been used to locate icebergs in fog or darkness and obviously can be used to detect the presence of ships. For the measurement of distance a maintained sound is not required, but rather one single distinct sound which can be timed. Some devices use a small detonator, others a hammer striking a metal disc. Whatever method is used, the time interval between the emission of the sound and its arrival back at a microphone is automatically recorded.

The most important application of this principle is, of course, echo sounding. If the sound is sent downwards and the time taken for it to be reflected from the sea bed is measured, the depth of water under the ship's keel can be found quickly and with great accuracy. Depths can be recorded on a chart and taken so rapidly that the chart actually shows the contour

A.A. Searchlight

of the sea bed. A series of readings will show the presence of even a wreck on the bottom and no doubt this device could be used for locating a submarine which was lying still without its motors running.

With the great improvement in detecting devices the principles of which I have briefly described, the submarine has undoubtedly become more vulnerable. At present a silent submarine is an ideal quite beyond attainment since not only does the engine make noises which are transmitted to the water through the hull, but the propellers themselves by the very nature of their movement set up vibrations. Each blade of the propeller as it revolves produces a "cavitation" and a succession of these produce waves which can be turned into sound waves in air by hydrophones.

The safety of millions may depend upon the skill of acoustical engineers in a future war, for sound detection has become a very important part of defence against air raids. The sound detectors are really the first line of defence, if we exclude observers on ships at sea, and even they may use sound detectors, for an aeroplane can be heard long before it can be seen, not heard with the naked ear, perhaps, but certainly with special instruments designed to catch the faintest sounds or to amplify them until they can be heard distinctly.

Several types of detectors are used, the commonest perhaps being that of "trumpets". Here, the principle is the one already mentioned of two trumpets fixed on a line and moved until the sound comes with equal intensity to both ears, when the direction of the approaching plane is on a line at right angles to the line joining the two trumpets. In dealing with aircraft

we have an additional dimension; the trumpets, therefore, are placed in pairs, one to deal with the horizontal direction and another with the vertical. Each pair of trumpets is worked by one man. A third man performs the necessary calculations, which are not quite so simple as might be supposed, for in dealing with bombers you have the source of sound moving towards you at between one-quarter and one-half the speed of the sound they are making. This calculation is now greatly simplified, being made faster and more accurate by mechanical aids.

The increasing speed of aeroplanes compared to the velocity of sound to which reference has been made has encouraged research into alternative methods of detection and success is being claimed with devices that detect, not the sound emitted by the aeroplanes, but the reflection of ether vibrations, on the principles of "echo sounding". This has the advantage that there is no loss of accuracy if the aeroplane is hidden by cloud. Extremely sensitive methods of measuring minute quantities of heat also suggest that aeroplanes can be detected by means of infra-red rays. When it is remembered that the heat of stars many billions of miles away has been measured by means of sensitive photo-electric cells the possibility of detecting the approach of an aeroplane twenty miles away does not seem so difficult.

To the skilled observer the sounds indicate not only the direction of the approaching aeroplanes, but also their number, probable types and approximate speed, all important information for the other units of the defence, the searchlights, gunners or interceptors.

How vastly sound detection has improved since the Great War was indicated a short time ago when a sound observation post in Belgium detected the presence of an unknown aeroplane that had crossed the frontier, even though it was out of sight, sent information to fighters and had it forced down before it could return.

The fact that it is sound which betrays the presence of bombers, has led aircraft constructors to seek a silent machine. This is an ideal very difficult to achieve, although insufficient attention has been paid to the problem. Noises in an aeroplane come from two distinct sources, the exhaust and the propeller. The usual engine noises and possible flutter of material is of comparatively little importance at a distance of a few miles. By some slight sacrifice of power and addition to weight it might be possible to produce an aeroplane that was without exhaust noises, but many pilots dislike the idea of hot silencers in proximity to the fuselage. The elimination of propeller noise is more difficult and hardly possible without additions to normal propeller design. Silent flying would be a boon in times of peace but would vastly increase the danger of the bomber. It is true that a certain amount of research has been conducted on the subject and many stories have been told in recent years of "silent aeroplanes", but if any of the air forces have solved the problems involved, they have kept their secret well. Even steam-driven aeroplanes with ultra-large propellers have been tested on many types of aeroplane.

The "silent raids" made by German bombers in Spain depended upon the new trick of ascending to a considerable height and then gliding, perhaps ten

miles, towards the target with the engine switched off. This enabled surprise attacks to be made, but it is doubtful whether it would be so effective against a country with well-organized anti-aircraft defences. The aeroplanes would be detected by the sound-detectors before they cut out their engines while the loss of height might make them easier prey to both guns and intercepting aeroplanes. Nevertheless, these tactics will act as a further stimulant to the production of devices that will detect aeroplanes by waves other than those of sound.

One other military acoustical device with which we have become all too familiar in recent months must be described. This is the siren, now generally adopted for giving air raid signals. Most of the sounds we hear such as those of the human voice, or the piano are made by resonance. The siren produces sound in quite a different way. In the simplest siren the sound is generated by placing a nozzle, from which air is being forced, just in front of a revolving disc with many holes bored in its edge. The pitch of the sound produced as the air is alternatively admitted and cut off by the holes is dependent upon the number of holes and the number of revolutions per second of the disc. In other words, the number of holes remaining constant, we can raise the pitch of the sound emitted by increasing the speed of the disc. Sirens may be driven electrically or by compressed air. In the centrifugal siren, instead of the holes rotating they are cut in a stationary casing, while a wheel with vanes on it revolves inside. As the vanes travel round they open and close the holes in the casing. Air drawn into the siren is expelled

by the centrifugal action of the wheel. The sound produced is very powerful and travels considerable distances. In deciding upon the right note for warning sirens, experts had to take into account the fact that they would have to be heard above traffic noises.

One other point is worth mentioning. In the Great War noise itself accounted for quite a number of casualties. We know that quite apart from the danger associated with it, noise can produce ill-health and sickness, but this is due as much to the kind of sound as to its intensity. Just as sounds can become so faint that they pass the threshold of audibility and cannot be heard, so they can become so loud that they are more felt than heard. This may sound paradoxical, but what happens is that when they are too loud to be heard they are sensed and become very painful. A sound might be so intense that it kills by its wave front and this effect, no doubt, was sometimes responsible for the condition of shell-shock. The continual sound of a gun being fired at near range can produce nausea and headache. A certain amount of protection is afforded by stuffing the ears, but sound reaches the ear-drums through the bones of the skull, the mouth and other sources. Owing to the pressures experienced, it often gives relief to swallow hard to equalize the pressure inside the ear-drum. Airmen flying high will chew gum for this reason. Noise may eventually become a weapon in itself. Fear and noise are very commonly connected.

CHAPTER VIII

CHEMICAL WARFARE

THE USE OF CHEMICALS to poison, burn and even to conceal the presence of troops in warfare, is by no means new. As far back as the seventh century liquid fire was known and irritant vapours were used in wars before the Christian era. But owing to the very limited knowledge of chemistry and the lack of suitable methods for carrying the vapours to the enemy, gas warfare was of little importance prior to the twentieth century. It was, in fact, rather amusingly, "outlawed" at the Hague Conference in 1899, and this agreement to refuse poison gas or "weapons likely to cause unnecessary suffering" probably fairly well represented the feeling of the nations. Some fifty years earlier the British had rejected the idea of using poisonous vapours against the Russians in the Crimean War on the grounds of humanity. The vapour suggested was that formed by burning sulphur which would have been carried by the wind towards enemy positions. This was the vapour used in the dawn of civilization, so it will be seen that chemical warfare had not made much progress in twenty-three centuries.

Before explaining the nature and uses of modern

poison gases it would be right, perhaps, to examine this question of humanity and the banning of chemical warfare. First of all there is the point, that as we cannot "outlaw war" by agreement, you cannot effectively outlaw certain weapons. We can certainly pass resolutions and sign agreements not to use certain weapons, but since war itself involves the breaking of agreements, it is doubtful whether, in practice, the special agreement relating to the weapons used will ever be observed. In the case of poison gas it would be particularly difficult to ensure that it was not manufactured for the chemicals used in modern poison gases are very closely allied to many used in ordinary industry. To make the poison instead of the commercial product is simply a matter of slight alterations to plant, and every chemical works is a potential poison gas factory, capable of being adapted in the course of a few days. It is simpler, if equally absurd, to "outlaw" a naval weapon such as submarines, because these cannot be built secretly or quickly. From explosives to aeroplanes there is no form of manufacture which has not, with slight alterations, its uses in time of peace.

Poison gas is regarded as an evil weapon and there are, no doubt, millions of people who while they have no special objection to high explosive shells or bayonets, would heartily agree with the banning of poison gas on the grounds of humanity. In my opinion this view is based on a complete misunderstanding. Whether it is better to be poisoned by mustard gas, torn to pieces by a hand-grenade or disembowelled by a bayonet, is a matter of personal taste. Personally I think there is little to choose between their degradation. The fear of

poison gas is largely psychological and this valuable feature as a weapon is reduced with trained troops when the effect of the gas is so largely limited to the handicap it imposes by making the men work in special equipment.

I shall be reminded, no doubt, that the effects of poison gas may be lingering, that those attacked may feel the effects for years. This is true. It is also true that there is no weapon that can guarantee immediate disablement with no after-effects. It is ridiculous to suggest that the man who has had his leg blown off by a shell does not feel the after-effects for the rest of his life, and if you visit those hospitals where unfortunate soldiers are still receiving treatment for war wounds you will find that more of them are casualties of high explosive than of gas. In fact, gas offers the one possibility of a humane weapon, since there are poison gases which blind people temporarily, making them casualties for a few hours or days, but do no permanent damage at all. The ideal of an "anæsthetizing gas" might make war comparatively humane since it would be possible to put a nation to sleep until such time as their country had been occupied. It seems impracticable to suggest that by the time a method is discovered of applying such a gas we shall have reached a stage where we no longer need its aid.

This is not a defence of chemical warfare. I am simply pointing out that if we must have war, poison gas is no more inhuman than any other weapon. Actually the proportion of deaths to casualties in poison gas is much lower than from other weapons. For instance, casualties from poison gas in the British army

in the last war totalled nearly 181,000 with 6,000 deaths. This gives a mortality percentage of little more than 3 per cent, whereas the mortality percentage from other causes was as high as 25 per cent. In other words, if you were a casualty from poison gas your chance of living was nearly eight times as great as if you were a casualty from shell fragment, bullet or bayonet wounds. The casualties from poison gas in the Great War do not compare with those from bullets and high explosive. It is estimated that there were twelve deaths from bullets and seven from high explosives for every one due to gas.

The position regarding chemical warfare at the beginning of the Great War was that none of the combatant nations had made any preparations to use poison gas, or at least had any proper equipment in readiness. The matter had undoubtedly been the subject of research, in spite of the Hague Conference, and the Germans with their vast dye-industry had the material ready at hand. The motive behind the first gas attacks was not, as is so often popularly stated, pure "barbarism", but partly economic and partly tactical. Until development of the Haber processes the blockade was preventing Germany getting the nitrates essential for the manufacture of high explosive and an alternative weapon had to be found. Further, the consumption of high explosives and lead had exceeded all expectation during the first months of the War. Munition factories could not keep pace with the demand, increased when systematic trench warfare began and when no advance was possible without a vast artillery preparation. These were the economic motives. The tactical motive was

the realization that trench warfare was becoming a stalemate and that unless some devastating new weapon were introduced, the war would become one of exhaustion with the scales weighted against Germany because of the superior resources of the Allies.

As a matter of fact the Germans do not themselves appear to have believed very greatly in poison gas, otherwise they would have made the initial attacks on a far greater scale. What might have been a decisive weapon, simply because of the surprise element, was used only on a very limited front. The famous poison gas attack on April 22nd, 1915, when the gas used was chlorine was not the first use of poison gas in the Great War. The Germans had already used other gases, fired in shells, on a small scale both on the Eastern and Western fronts and perhaps it was the lack of success of these shells, or a complete under-estimation of the damage that could be done by poison gas against unprepared troops that led to the warning being foolishly neglected by the Allies.

The effect of the first attack, carried out very simply by allowing chlorine gas to escape from cylinders and to be blown towards the Allied trenches, was devastating. There were 6,000 deaths among the unprotected troops and a front of about four miles was left almost deserted. From this date gas became one of the great weapons on the Western front and a gas mask as much a necessity to a soldier as a rifle. The Allies replied to the Germans in kind and it is worth noting that chemical analysis has reached the stage where any "new" gas can be quickly identified and imitated. No one combatant can keep its secrets for long.

Some three thousand different poisonous gases were examined by chemists working behind the lines and although only a very small percentage of these were ever used in warfare, a dozen different gases were commonly employed, so possibly the best way of dealing with them is to consider the qualities desirable in a poison gas in warfare and then the different types used. In passing, it is doubtful whether any new poison gas, bacteriological or otherwise, suitable for military purposes has been discovered since the Great War. The stories of the "ideal" gas which we sometimes read about in headlines, are mostly imaginary. Research in this section of chemistry, as in every other branch, is not a matter of chance but of systematic work which was mainly covered during the intense research of the Great War. All nations have now their experimental chemical warfare camps, but progress has probably been limited to improvement in the methods of distributing already known gases. For purely technical reasons, I am inclined to discount the reports of deadly new gases. When we consider that a number of gases were used in the Great War which in a concentration of 1 part in 10,000,000 were sufficient to incapacitate a man, it is readily understood that the searcher for something more deadly has a difficult task.

The first essential of a poison gas is that it shall be easily manufactured from conveniently obtained raw materials. But there are many poison gases, easily produced, which cannot be used for chemical warfare because of their physical properties. For instance, there is carbon monoxide, as deadly as most gases, with the advantage that it is odourless; but it is lighter

than air and therefore, except in a closed room, never likely to reach the concentration necessary to make the air poisonous. It is often produced in the exhaust of a car, but if the garage doors are open, it is not likely to reach poisonous concentration by itself. Many tons of it released in the open air would escape upwards before it could cause a single casualty.

A poison gas must, therefore, be heavier than air and this immediately eliminates a very large number of the known poison gases. It must also be effective in very small concentrations, since it will become mixed with air immediately it is released. The concentration necessary varies from about 1 in 10,000 parts with chlorine, to 1 in 10,000,000 with some of the gases affecting the eyes and nose. With the introduction of gas masks it became desirable that a gas should, if possible, give no warning of its presence; but the odourless gas that has the other qualities necessary is very difficult to find.

In fact most of the poison gases used were not gases at all, but liquids which when finely divided in a spray or slowly evaporated and gave off deadly fumes. The most widely used gas towards the end of the War and the one which it is taken for granted would be used in future hostilities, is mustard gas, a liquid with a boiling point higher than that of water.

Poison gases could be divided according to the centre which they attack. The first gases extensively used were aimed at the lungs. The original German gas attack was made with chlorine which was easily available from chemical works. This is a heavy green gas which can be compressed and released from cylinders.

Its disadvantage is that its colour immediately gives warning of its presence and that because it is only effective in comparatively high concentrations, huge quantities have to be used. About one part in ten thousand of air gives an incapacitating concentration and although this may sound very little to the layman, it means that the gas must be released in clouds. Most people who have worked in laboratories have had a whiff of chlorine without doing themselves any damage. There is the further disadvantage that a comparatively simple gas mask gives effective protection against this gas. On the other hand the damage inflicted is very often permanent. It is unlikely that chlorine will be extensively used in future, certainly not any rate against protected persons.

The other common gas used for attacking the lungs was phosgene, a combination of carbon, oxygen and chlorine. This is at least ten times more deadly than chlorine and was widely used throughout the War by both sides, sometimes alone, sometimes mixed with chlorine. Chloropicrin and trichlormethylchloroformate were two other poison "gases" used to attack the lungs, although at ordinary temperatures they were liquids and it was the vapour that did the damage.

Then there are gases which attack the central nervous system, the most effective one being hydrocyanic acid gas, probably the most deadly gas in the world, causing instant death when breathed in concentration. But the concentration required is comparatively high, one part in two thousand and although used by the British, it was not used in large quantities.

Another class of gas is the lachrymators, so-called

because they affect the eyes, causing temporary blindness. The injury is temporary and in a short while the victim may recover completely. These are the "tear gases" used for dispersing crowds or catching armed criminals. The commonest is xylyl bromide which, in fact, was the very first poison gas used in the War being employed by the Germans in 1914. Ethyl iodacetate, used only by the British, is effective in smaller concentrations, one part in five million being sufficient to cause a casualty. In stronger concentrations it attacks the lungs by cumulative action. Both these gases are liquids at ordinary temperatures, being dispersed as a fine spray.

Another class of gas, actually solids at ordinary temperatures, attack the eyes, nose and lungs. They are used as very finely divided particles, distributed by the burst of a shell and since they penetrated a gasmask unless it was fitted with a special filter, the object was probably to cause sneezing inside the mask and force it to be removed. These gases, all compounds of arsenic, were used exclusively by the Germans.

Finally, we have the class of gases known as vesicants because of their burning action on the skin. The only completely satisfactory and widely-used one is mustard gas, chemically, dichlorethylsulphide; a liquid at ordinary temperatures, with a boiling point of 443 deg. F. and a melting point of 57 deg. F. It attacks the skin by blistering and the eyes or lungs by the vapour which is slowly given off. The effects are not immediately perceived, which makes the gas all the more deadly. Mustard gas combines an attack on the lungs, throat and eyes, with one on the skin itself. Twenty

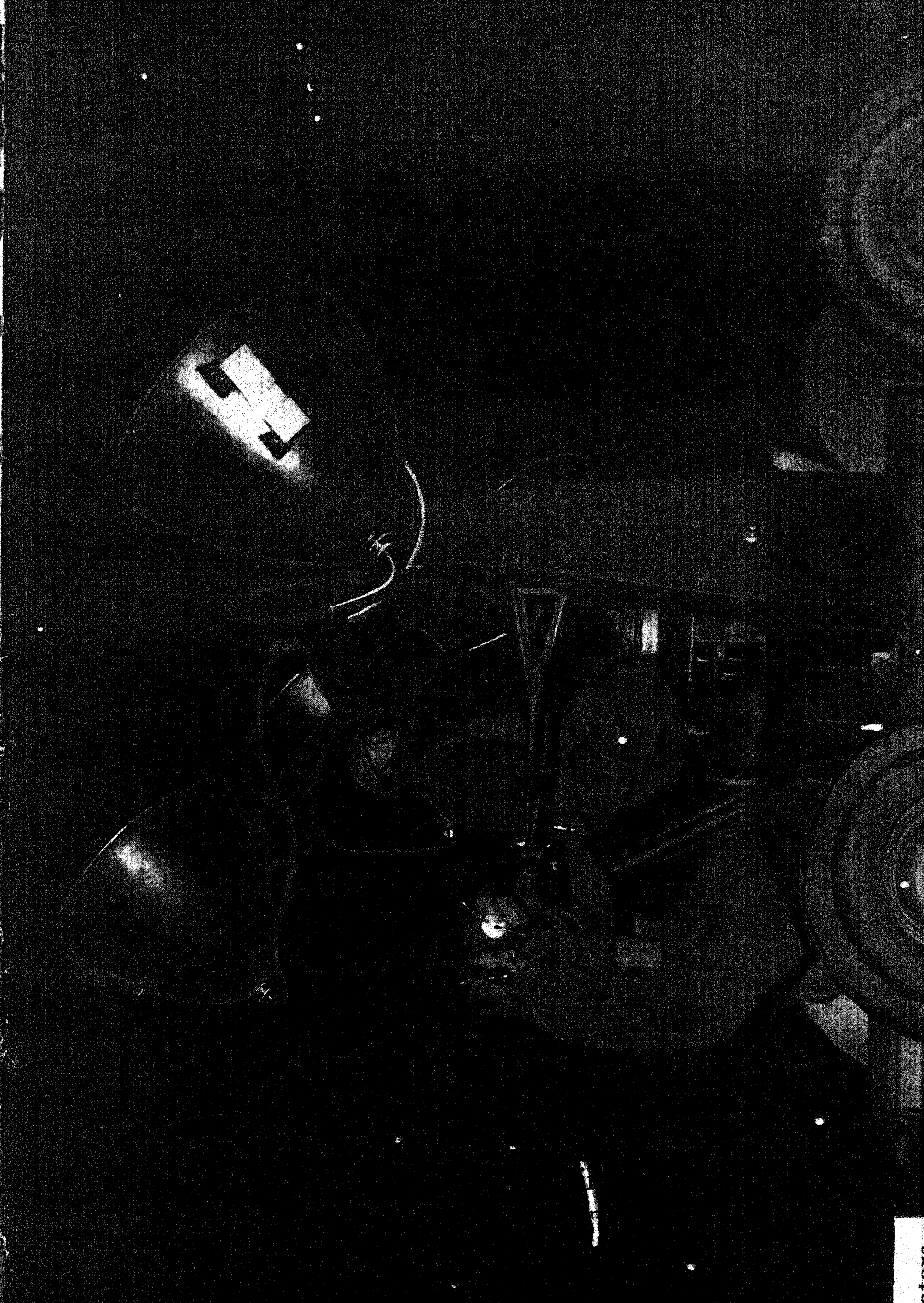
milligrams of mustard gas in the lungs are sufficient to cause death. It is this gas which it is anticipated would be most widely used by air-raiders in any future war. It has only a slight smell and therefore may give no warning of its presence. On the other hand if the presence of mustard gas is suspected it can be quickly detected by a chemical reaction which can be performed by a trained man who need not, necessarily be an expert chemist. Special units for decontaminating areas over which mustard gas have been sprayed are now equipped. A typical equipment is a motor vehicle carrying 700 gallons of water, with a high-pressure pump and pulling a trailer carrying chloride of lime. The men are equipped with special protective clothing. They neutralize the mustard gas by scrubbing with chloride of lime and then turn on the hose which sweeps the substance into the drains.

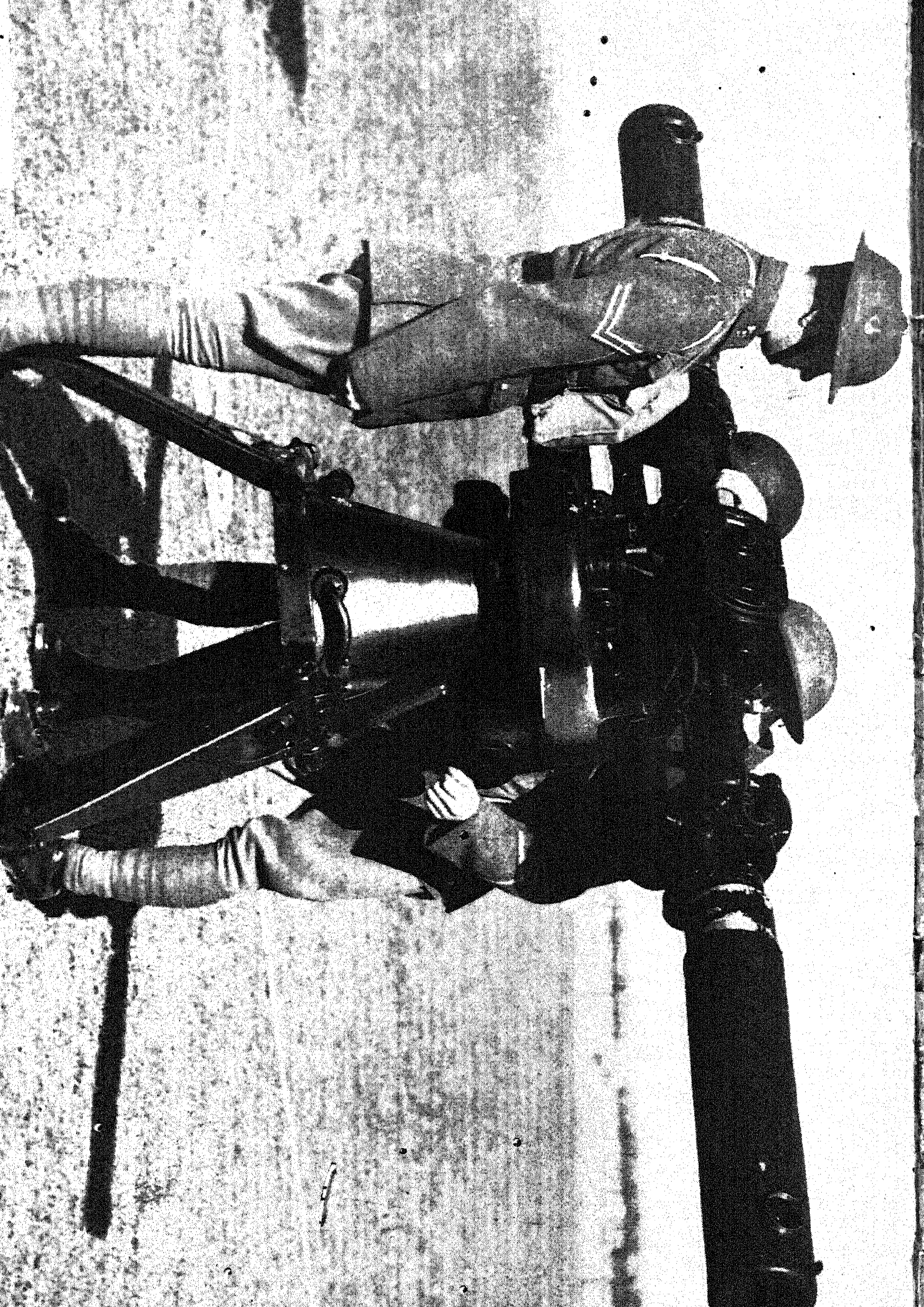
Broadly, there are three ways in which gas can be distributed; which of them is chosen depends upon the conditions, the effect desired, and the gases used. The simplest method is to release the gas from cylinders when the wind is blowing towards the enemy. This is the way the ancients used their vapours, and the method first used in the War. The opportunities for using it are limited, owing to the wind, and it is worth noting that although the Germans in the Great War introduced it, in the end they suffered most because the prevailing wind was towards their trenches. There is always the danger, of course, that the wind will change to blow the gas back, and the further point that it is generally immediately obvious to the enemy from what direction the gas is coming so that the men

actually releasing the gas become targets. There is the further point that the advancing gas cloud gives warning and time for gas masks to be adjusted. This method of releasing gas was less and less used as the Great War progressed.

Another method by which gas can be released is by spraying from aircraft. Cylinders of the gas or containers of the liquid or powder are fitted to the aircraft which flies low, releasing the gas which slowly falls. This method enables a fairly large area to be effectively covered in a short time. Special apparatus has to be installed to overcome the effect of the forward speed of the aeroplane. The method has the considerable disadvantage that unless the aeroplane flies very low, when it becomes an easy target for the modern quick-firing cannon, most of the liquid will evaporate or diffuse before it reaches the ground. If gas is used from any considerable height it will become so diluted by the time it reaches the ground that it will be ineffective. Altogether it may be supposed that the method of distribution by spraying would not be effective except against unprotected civilians in limited conditions which would include the absence of appreciable wind to blow away the vapour.

The chief method of distribution in modern warfare is by gas-filled projectiles, either shells from guns or bombs from aeroplanes. For this purpose, the shell or bomb is given only a small "opening" charge of explosive which scatters the liquids, solids, or releases the gas stored under pressure. Towards the end of the Great War a vast number of shells were fired and in some actions as many as eighty per cent of the shells





were gas-filled. Phosgene and mustard gas, as well as the "solid" gases were distributed in this way, the advantage being that the gas could be dropped if desired on lines of communication which could not be reached by gas clouds released from the front line. For shelling front line trenches with gas, a special mortar was introduced by the British which fired a projectile containing no less than 30 lbs. of gas. The technique was to fire a battery of these at a single target producing a concentration of gas without giving any warning.

Every offensive weapon immediately calls forth its defensive reply. Although the British and French were caught completely unprepared by the first gas attack, within a few days they had a crude pad which could be placed over the mouth and nose. Fortunately, the opportunities for using cloud gas attacks were few and chemists had reasonable time to prepare protection. In actual fact, from the middle of 1915, the gas-mask was generally ahead of gas; that is to say the use of new poison gases was anticipated and a method of absorbing them in gas masks devised before they were used by the enemy. The first protection was not given by masks as we understand them to-day, the necessity for covering the eyes did not really arise until lachrymators and irritants of the eyes were introduced.

The use of vesicants called for still further protection of the exposed parts of the body and to-day protective clothing is manufactured for the use of those who have to work where it is suspected that "mustard" has been distributed. The liquid sticks to ordinary clothing which gives no protection, although if the clothing is immediately stripped off the damage done may be small.

Complete protection against mustard gas is probably impossible to achieve. The methods by which it can be countered are the provision of a mask which absorbs the vapour and renders it harmless before it enters the mouth or nose, seeking cover against being splashed by the liquid and marking out areas which have been contaminated by the liquid so that they are avoided by unprotected persons until the liquid has been neutralized, or rendered harmless with chloride of lime, by persons specially equipped. While mustard gas is the most effective poison gas known, it has the disadvantage that its effect is entirely local and limited to the immediate vicinity of the point where the bomb or shell containing it has exploded.

A normal gas mask consists simply of a filter and absorbents for removing poison gas from the air before it is breathed. Many different types are made, but all contain an inlet valve through which the air is drawn by inspiration, a filter and solids for absorbing the particular gases expected. There is always the possibility, of course, that the mask may be made ineffective by the use of a gas for which it contains no absorbent, but for reasons that I have explained, the chances of this happening to-day are remote, since practically all the poison gases suitable for military purposes have been examined. The exhaled air is allowed out of a mask by a valve which may be a very simple affair as in the ordinary civilian respirator distributed in Britain, or more elaborate in the Service mask. Whether the canister is on the chest or in front of the nose is merely a matter of arrangement. With a mask to be used while working, it is essential that the maximum amount of

air should be drawn in without effort, a man moving about requires far more air than a man sitting still, and the chest canister mask is more efficient from this point of view. An alternative type of mask, little used for military purposes but used where carbon monoxide is suspected as in mine explosions, has no connections with the outside air, the oxygen being supplied in the respirator and the carbon dioxide absorbed by chemicals.

The effect of defensive measures against gas can be judged by a comparison of the casualties caused early in the War and those caused towards the end. The first gas attack inflicted 6,000 fatal casualties in one single day with the release of a very limited amount of gas. In 1918, one ton of mustard gas was required to inflict a single death. In one of the heaviest gas attacks of the War between four and five hundred tons of gas were released on a 5½-mile front, the gas penetrating up to twelve miles behind the lines. This worked out at one ton of gas per twenty-two yards of front. The result was about 500 deaths and 1,600 casualties, so it is impossible to overlook the view-point that the expenditure of the same weight of high explosives would probably have caused much heavier casualties. Efficiency is best measured by death or mutilation in these cases.

What is the future of chemical warfare? No one doubts that poison gas as a weapon has come to stay, certainly until such time as the nations agree to abandon all weapons. Many people seem to imagine that the next war will be fought almost entirely with poison gases fired from guns and dropped in bombs. The extent to which this weapon will be used will depend

upon its effectiveness and since twenty years have passed since the War during which defensive measures have progressed but the offensive use of gas has progressed little, it is difficult to anticipate exactly how effectively gas will now work out in practice. The general opinion is that its usefulness will be more psychological and hampering than casualty-causing.

For use against armies, the chief value of gas to-day is not so much the infliction of casualties as forcing troops to put on gas masks, which make working far more exhausting than in the "open air". Moreover, by shelling areas with persistent or "cumulative" materials such as mustard gas, they can be made untenable until after decontamination, a process which would take some time. These values remain whatever the protective measures adopted, but as they are open to use by both sides, the effect is often neutralized. The advance of an army can be held up and the speed of warfare reduced. It must be remembered that just as infantry of the attacking side cannot advance into a gas cloud they have themselves released, without masks, so they cannot advance into a country which they have drenched in mustard gas. One would not anticipate a great number of casualties among the well-protected and trained troops of to-day, but the constant watch that has to be kept for gas, the persistence of mustard gas which is effective for days and the exhausting effect of wearing gas masks for long periods on end will probably result in gas continuing to be a good weapon.

The possibilities of successes being gained by the use of "new" gases as in the Great War are now remote. Chemists engaged in defensive measures are now, if

anything, ahead of their colleagues engaged in the search for new substances. At the end of the Great War the Allies had prepared a vast quantity of a "solid" gas, Adamsite, with which they proposed to deluge the enemy position in preparation for a tremendous attack by infantry. The Armistice prevented this plan being put into action. It might have been successful in 1918, but probably would not be so to-day.

In the case of gas, dropped in bombs or sprayed from aircraft, against civilians, there are many quite different considerations. For a completely unprotected people, a gas attack might be effective, although it is doubtful whether it would be more destructive than an equal weight of high explosive. The effect would probably be largely psychological, gas being unknown to the average civilian. But against a nation whose people have had some education with training, and who are equipped with gas masks or gas-proof shelters, the probability is that gas would be comparatively ineffectual, although its "nuisance value" might be high.

We read that one ton of mustard gas is sufficient to kill some thousands or millions of people, that a few score aeroplanes could carry enough gas to envelop the whole of London in a gas cloud that would mean death to everyone beneath. These statements are grossly misleading. It may be true that a ton of mustard gas could kill a million people, but this presupposes that the victims will each deliberately breathe in just sufficient to kill them, under laboratory conditions, and take no steps whatever to protect themselves. Laboratory conditions are very different from those found in actual warfare. In fact it is possible to have complete

protection from phosgene and mustard gas, the only two gases that are likely to be used in bombs, by simply going into an airtight room during the period of danger. In the case of phosgene, the gas would probably be dispersed in about half-an-hour. In the case of mustard gas the persistence is much longer, but fairly simple gas masks give protection even in the immediate vicinity of the explosion. It is likely to be found that against a well-prepared civilian population the amount of gas required to cause death would be about the same as on the Western front; a ton. To drop sufficient gas to cause serious casualties in London would call for thousands of aeroplanes flying in relays night and day; always assuming, of course, that they are not menaced by anti-aircraft fire or other defensive measures.

From a period when everyone seemed frightened to death of gas bombing we seem to have passed to one in which there is a tendency to underestimate the damage that might be inflicted and it should be carefully noted that in the rough figures I have given above, I am speaking of a well-prepared population. Every soldier is given a thorough training in the task of protecting himself against gas. He carries his gas mask at all times, puts it on immediately there is a gas warning and does not take it off until he gets the All Clear. It is not sufficient to provide gasmasks. This must be accompanied by education of the public in the physical properties of the various gases, even though this education is very elementary. When once this is accomplished, the effect of a gas attack on civilians is likely to be so small that the enemy will be discouraged from further attempts.

Poison gas is the chief item in chemical warfare, so called, for really high explosives and even the manufacture of fine steel for a bayonet is just as much "chemical" warfare. Of the other chemical weapons there may be mentioned, flame-throwers, smoke screens and rockets for various purposes.

The flame-thrower was introduced by the Germans and subsequently taken up by other combatants. The idea of inflicting casualties by projecting burning liquid is, of course, very old and the modern version is simply an improvement in the methods of projection. The flame consists of ignited paraffin, petrol or heavier oils and it is usually driven by non-inflammable gases kept under pressure, a range of over 100 yards being attainable, although the range of the smaller portable flame-thrower was nearer 50 yards. The machine was fairly simple in construction, consisting of a container for the inflammable liquids from which they were forced by nitrogen, air, or carbon dioxide held under considerable pressure in a strong cylinder passing through a small nozzle at the exit of which they were ignited. The flame-thrower was "fired" by a trigger which in fact simply opened valves from the gas chamber. The users, of course, had to wear special protective clothing.

The effect of this weapon even on seasoned troops was considerable, not because of the casualties inflicted but because of the terrifying appearance of the tongue of flame as it swept along scorching everything in its path. But like so many "terror" weapons, its use was extremely limited for a number of reasons. It could only be used for a short time before the gas and fuel had to be replenished, its range was very short and the user

made himself an easy target since the weapon had to be used in the open. The weapon was very heavy and therefore not easily portable. When the operator was struck by a bullet there was a very good chance that the flame would sweep round and destroy not only himself but any soldiers on his own side nearby. Bearing in mind these disadvantages and the fact that there will probably be an oil shortage, it is unlikely that this weapon will play an important part in future war, except in local actions. Certain "electrical fire" experiments have been made recently and have achieved considerable success.

In ancient times "Greek fire" as this incendiary weapon was called, was fed chiefly with pitch and sulphur which was melted for pouring down by the defenders of a fort, or thrown against wooden defences by attackers. Later, naphtha was added and there seems to be some evidence that even raw petroleum was used. The most effective form of this weapon seems to have been a mixture of naphtha, sulphur and quicklime projected at enemy ships. Water was squirted after the mixture so that the heat generated by the quicklime with water helped to ignite the naphtha and sulphur. For the most part, ancient flame-throwers seem to have been used against material rather than personnel, whereas the contrary is true of its modern counterpart.

Until the invention of smokeless powder, all battles since the introduction of gunpowder has been fought in a more or less dense cloud of smoke. The first volley of musketry set up a cloud which screened the enemy and this may have accounted in some degree for the lack

of damage often done in spite of the shortness of range. Smokeless powder introduced certain advantages, but there are occasions when attackers or defenders may desire to conceal themselves and for this purpose the chemist invented a shell specially designed to produce smoke, as well as smoke clouds that could be laid as a screen by aircraft.

The smoke purposely used for concealment in former times was generated by burning wet hay or some similar substance. Chemical smokes were not really introduced until the Great War and then not widely used until 1917. The value of smoke in concealing an attack as distinct from covering a retirement was realized comparatively late. An essential point in the modern use of smoke is that it shall be generated in front of those wishing to take advantage of it and not by them, smoke generated at a battery of artillery with the idea of concealing it, for instance, would merely have the effect of making it an easier target. At sea, smoke may be deliberately produced in the furnaces of ships with the idea of enveloping them in an impenetrable cloud.

The possibility of firing smoke-shells so as to produce a concealing cloud or to lay a screen from an aeroplane has called for new tactics in war. The purposes for which concealment may be used are many. At Zeebrugge, small motor-boats laid smoke screens in front of the larger vessels so as to mask the movement of the blockships from the enemy. On the Western front smoke screens laid by artillery were used to conceal advancing troops and make observed fire at them impossible, to mask exposed flanks and various evolutions.

The chemicals used for producing smoke are titanium tetrachloride and white phosphorus, both of which ignite with the emission of a vast amount of very finely-divided white solids. It has been suggested that smoke screens might be used for concealing whole towns from aerial bombardment, but it must be remembered that even given the ideal day on which the screen would not drift away or be dispersed rapidly by the wind, it would actually mark the target and while it might conceal the exact position of, say, an important factory, in fact it would indicate its approximate position. The difficulty of using smoke screens at high altitudes to envelope raiding aeroplanes is the comparatively rapid dispersion of the cloud and the fact that modern aeroplanes would fly through a cloud several miles long in a few minutes. It would be more effective to produce a cloud of poison gas, although the occasions on which this could be effectively done would be exceedingly limited. When smoke screens are laid by aeroplanes, as for instance in front of a fleet, the apparatus used is very similar to that employed in sky-writing, the smoke being emitted from a nozzle, and the finely-divided solids, although heavier than air, remaining partly suspended because of their complete dispersal.

The chemist also supplies rockets for signalling, a code of signals being arranged according to the colours fired. The various colours are obtained by the use of different elements in the charge, strontium produces red, magnesium, white, for example. Convenient methods of discharging these rockets in a pistol have been devised. Another "firework" adapted for warfare is the star-shell, a shell containing a low bursting

charge and a small parachute carrying a flare which is ignited and drifts slowly to earth illuminating everything below. Flares of many different kinds are used for signalling or illumination and during the Great War some were made to give up to 1,000,000 candle-power for the Dover submarine barrage. Most of these chemical aids to warfare are more likely to be developed in method rather than superseded by any very great novelty in invention.

One more device is, to-day, of special interest, it is the "tracer" bullet which is really another development of chemical warfare. The tracer has a covering of phosphorus or other chemicals which are ignited by the friction of the air and therefore render visible the course of the bullet as it travels towards its target. The general practice was to place these bullets at intervals in a belt so that the gunner could see where his bullets were going and alter his aim accordingly. To be hit by a tracer is, of course, particularly dangerous; in some ways worse than with the explosive or expanding type. Other methods, mostly optical, have been invented so that a stream of bullets or ordinary or inertia guns can be seen through special telescopes. Accuracy in modern aircraft guns, even of the type firing a large number of small shells per minute, is seldom high owing to the difficult conditions of speed and wind under which they are expected to function.

CHAPTER IX

WARSHIPS

MANY BOOKS have been written on navies; it would be impossible to deal at all briefly with every aspect of an arm of defence in which Britain has specialized and which costs her more than £100,000,000 a year. I will therefore confine myself to certain aspects of warships or to one or two of the specialized ships; bearing in mind that the reason why a modern battleship of 35,000 tons costs upwards of £10,000,000 to build, or £500,000 a year to maintain, is not because it embodies any particularly novel principles, but on account of its size and complexity. A modern battleship is really a gigantic factory with the specialized job of destroying other ships while remaining afloat itself. It has an exceedingly complex organization and a large personnel, only a small part of which are really directly concerned in the firing of guns. As with every scientific weapon of war, three or more men are required to look after each one who is actually fighting.

The early history of the battleship, going back to remote times, is chiefly one of mounting increased armament to destroy less well-armed ships. The real history of the modern battleship begins with the

adaption of a number of inventions for the purpose of fighting at sea. These inventions were steam power, screw propulsion and armour. Steam power was taken directly from commercial shipping, and it took a considerable time for the navy authorities to be persuaded that it was of real value. This was partly due to the method of propulsion in general use up to the middle of the last century, the paddle-wheel, which was particularly vulnerable to destruction by shot. Two or three well-placed cannon-balls could destroy a paddle-wheel and put the ship out of control, whereas a considerable expenditure of shot or shell was necessary to reduce a sailing vessel to a state where it would not manœuvre. It was also due, of course, to the conservatism of the authorities who felt, and sometimes said, that the methods which had won the Battle of Trafalgar were good enough for all time. The Admiralty is quoted as stating that the introduction of steam would inevitably prove the downfall of the British Navy.

The invention of the screw propeller, a century ago, solved the problem of propulsion and made steam essential for all warships. The Admiralty took an early interest in this invention, but it was some years before they fully appreciated the great change it was to bring to fighting vessels. Even in the 'sixties, British warships were being "full rigged" and it is interesting to remember that the late King George V went to sea in a warship that used sails.

Steam provided the power necessary to propel armoured ships. Armour was virtually impossible with ships which had to be driven by the wind; the most that could be done was to build them of iron

which, unless it was thick, was little more resistant to shot than the old two-foot wooden walls. Armour of sorts had been used for centuries; leather or hides were used for the most part, with thick plates of copper or brass, but these were quite useless in the face of increasingly powerful guns; they became laughable with the introduction of cordite and high explosive. Wood had shown itself remarkably resistant to ordinary cannon-balls, the great danger being that of fire. In some instances ships had been treated with fire-proofing chemicals. But wood was no longer any use by the middle of the century and armour began to be fitted to the more vulnerable parts of warships. From 1860 onwards the story of battleships evolution became largely one of armour versus shells. As more powerful guns with armour-piercing shells were evolved, so armour became thicker and stronger. It was a battle between metallurgists in which the victory seemed to lie sometimes with one and sometimes with the other.

The first armour was of wrought-iron and the first armoured British warship was the *Warrior*, with armour-plates 4½ inches thick. But hardly had this ship been completed when steel shot came into general use and the next vessel, the *Bellerophon*, had armour 6 inches thick. The invention of armour-piercing shot of special steel necessitated increases in the thickness of armour until in 1881, only twenty years after the building of the first armoured vessel, it was 24 inches thick. At this rate it seemed as if ships would soon have to be built of solid iron.

Fortunately the metallurgist had a defence ready. The reason why steel plates had not been used for

armour was that although they were harder than wrought iron, they cracked more easily under the impact of several shots. What was required was the hardness of steel with the toughness of wrought iron and this was secured by compound armour-plates. These were made in various ways. In one process liquid steel was poured onto wrought iron so that the two metals flowed into each other giving a steel front with a wrought iron back. This compound armour was at least $33\frac{1}{3}$ per cent stronger than iron alone, and made possible a corresponding reduction in thickness to resist a given projectile. The period of compound armour lasted until the 'nineties when all-steel armour began to be made and various special processes were invented to increase its resistance. It is impossible to deal with the complex problems of metallurgy involved, but they amount to the treatment of the steel in certain ways, such as chilling with water under pressure, so as to increase hardness, toughness and resistance to cracking. Harvey of America introduced an important method by which carbon was absorbed by the steel at its face, the result being an armour twice as efficient as wrought iron. Nickel and chrome steels were introduced. Armour progressed to the stage where a 12-inch shell fired with a velocity considerably higher than that used twenty or thirty years before, was unable to penetrate a 12-inch plate of armour.

To-day the making of armour-plate for battleships is an exact science. The plate goes through a number of elaborate processes to make it immensely tough and hard, the exact measurement of temperatures for heating or cooling and the careful analysis of the con-

tents of the steel giving uniform results. The armour-piercing shell has also increased in efficiency so that the relative position now remains much the same.

The other most important part of battleship evolution has been concerned with mounting the guns. In the 'sixties, guns were still being mounted on broadsides in very much the same way as at Trafalgar. This meant, of course, that only half the ship's fire could be brought to bear under the most favourable circumstances. The evolution of larger guns implied that fewer could be mounted so that ways had to be found to make them available in as wide a circle as possible and for protecting their crews. This problem was solved by the invention of the turret, first used on the ironclad *Monitor* in the American Civil War and introduced into the British Navy in the *Royal Sovereign*. Since that time guns have always been placed in turrets or casemates.

The *Dreadnought*, built in 1905 as the result of a special committee which had sat to decide the future form of warships in Britain, was notable for several features, the emphasis being on the necessity for long-range guns and speed. Speed was obtained by the use of turbines in place of the older expansion engines. Ten 12-inch guns were mounted in five turrets and 24 small guns to deal with fast ships attempting to deliver a torpedo attack. Battleships have since followed this type in principle, the biggest advances being the introduction of "bulges" to negative the effect of torpedoes, it is estimated that five hits by a torpedo would be required to sink a modern battleship, of armour, and guns to deal with air attack.

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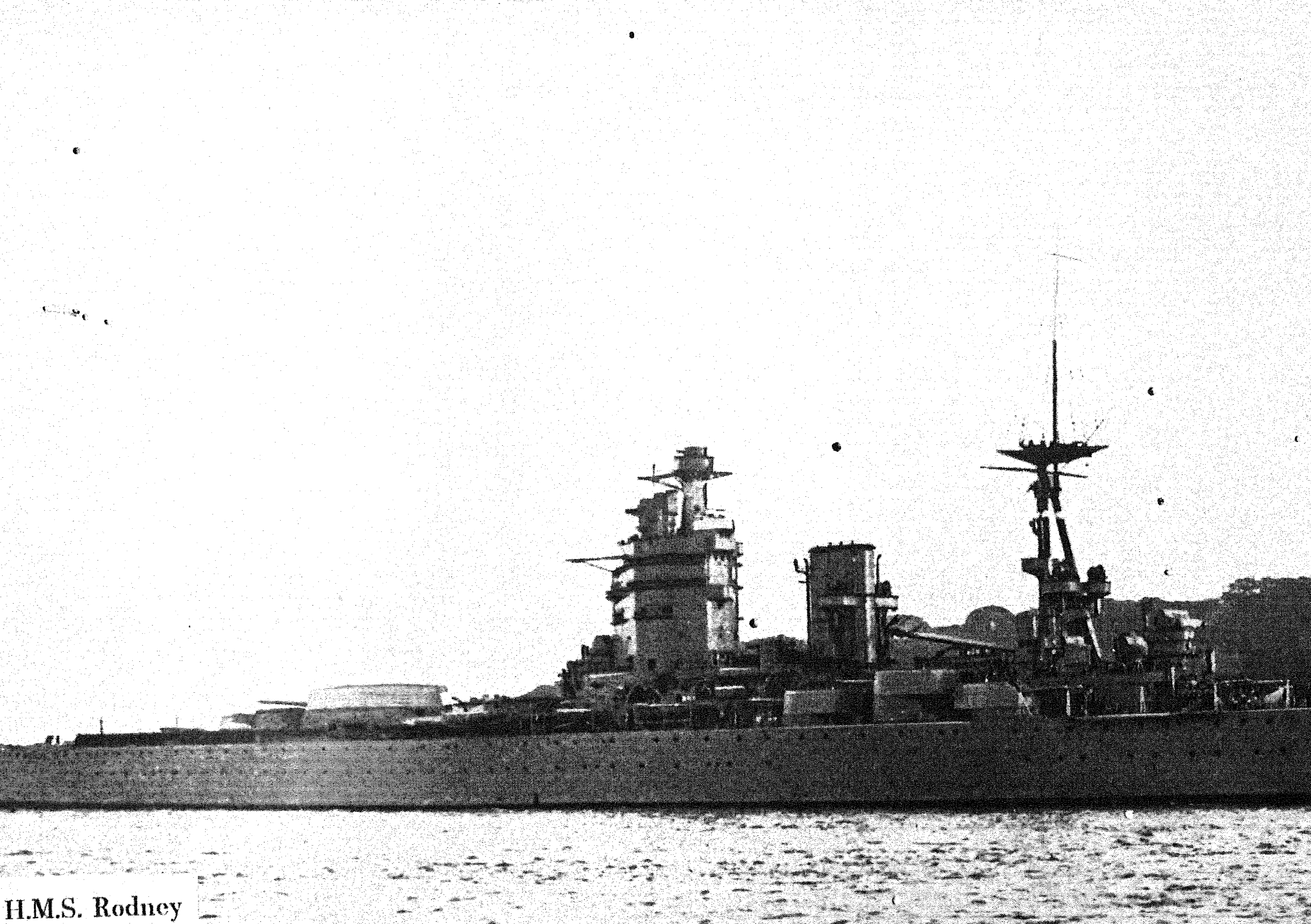


H.M.S. Rodney

It is interesting to compare the size and armament of the *Dreadnought*, built in 1905, with the *King George V* soon to be completed. *Dreadnought* was 17,900 tons; *King George V*, 35,000 tons. *Dreadnought's* maximum speed was 21 knots; *King George V's* is 30 knots. Against the *Dreadnought's* ten 12-inch guns, the new battleship mounts ten 14-inch guns. The tremendous difference in size is offset by the apparently small increase in speed and the weight of broadside. In practice, the increase is tremendous, for the power required to produce an increase of speed mounts rapidly as the speed rises. Moreover the increase of even one inch in the calibre of the guns means a great increase in weight which, in turn, means an increase in power if speed is to be maintained. The actual weight of a gun is not considerable compared with that of the ship. But the weight of the mountings brings it up to an average of 1,000 tons a gun in triple turrets for 16-inch guns. Reduce the calibre to 14 inches and there is a saving of about 2,500 tons per vessel. The idea of size and power is illustrated by a large ship requiring 40,000 horse power while a 15-inch gun may throw a shell weighing nearly 2,000 lbs.

All battleships are compromises and the task of the naval designer, using all the resources of modern science, is to make the best of the compromise according to the policy of the navy which is going to use the ship. The arrangement is between weight of armament, weight of armour and speed. By reducing the thickness and amount of armour, speed can be increased. At a sacrifice of speed, armament or armour can be increased. A means has to be reached for a

given size of vessel. Before the War the tendency was to sacrifice armour to speed and hitting power, but to-day it is realized that the sacrifice of an inch or two in calibre is well worth while to ensure the battleship performing its prime duty, staying afloat. This explains why the *King George V* class are equipped with 14-inch guns against the *Renown's* 15-inch guns. While the speed of the two vessels will be approximately the same, the *Renown* has only 9-inch armour against the *King George V's* 14-inch armour.

It has been said many times that the day of the battleship is over, that it is at the mercy of aeroplanes and the new fast motor-boats carrying torpedoes. Ten years ago even the advocates of big battleships were a little nervous as to the fate of their expensive fighting machines. But to-day that nervousness has disappeared, partly owing to the result of tests in which aeroplanes attacked target ships with bombs and partly to the great improvement in anti-aircraft defence. Old battleships have been refitted with offensive and defensive measures against aircraft; new battleships have been built with this object specially in view. In addition, a number of cruisers have been refitted specially as anti-aircraft attacking ships. They are, in fact, floating anti-aircraft batteries and might defend a whole fleet. The battleship which was said to be doomed by the torpedo, and again by the submarine, seems to have survived. In future hostilities it should show itself capable of dealing with aircraft while continuing to perform its duty of seeking out and destroying enemy ships.

In the end, victory may go to the side whose battle-

ships prove themselves superior. Generally speaking, all the cruisers, destroyers and other craft of the modern navy are based upon battleships. The cruisers and destroyers cannot keep the seas unless their own battleships have established supremacy. That explains why in the Great War, although Germany had numerous cruisers and destroyers they were rarely seen, whereas British cruisers or destroyers had the "freedom of the seas". The one exception, perhaps, is the submarine which can keep the seas in spite of battleships; but its work is made more dangerous if the enemy are able to maintain their small fast ships at sea in pursuit of the submarine. As far as battleships are concerned, the submarine bogey was effectively laid in the Great War where not one battleship was lost to a torpedo fired by a submarine in a fleet action. For attacking old battleships or those which are unaccompanied, the submarine is still dangerous, but it is now chiefly concerned with the attack of merchantmen. The most that can be said for it is that the threat of submarine attack hampers battleships quite seriously.

One of the most recent additions to the "specialized ships" of the navy is the aircraft carrier. The advantages of carrying aircraft on warships were early apparent. In the first days of flying, before aeroplanes carried armament of any kind, they were used entirely for scouting and spotting. For centuries the limit of a ship's vision had been determined by the height of her masts and, of course, the conditions of visibility. So long as the effective range of a ship's guns was limited to less than a mile, this was of no very great importance, for scouting work could be carried out by fast

small ships. But with the increase of range, accurate information about the position of enemy ships and of the effect of fire became of great importance. The aeroplane increased the visible range of a ship by many miles, even before wireless was fitted when signals between ships and aeroplane had to be made by means of coloured lights.

On the other hand, aeroplanes taking off from the land could not, because of their limited range and greater speed, effectively co-operate with a fleet at sea. The essential was for a ship to carry her own aeroplane and release it when required. This was accomplished in two ways during the early days of the Great War. Either an aeroplane was carried, to be catapulted from the deck of the ship, or a seaplane was lowered by cranes into the water. The catapulting method had the disadvantage that the aeroplane could not return to her "parent" ship but, after performing its work had to return to land. The method of catapulting or lowering a seaplane had the disadvantage that if the sea was at all rough, the seaplane could not come down to be picked up by the waiting cranes. Both methods had the disadvantage that only one or two aircraft could be carried. Nevertheless, these methods with improvements, are retained for warships. All the larger warships and a few submarines are equipped to carry one or two planes ready to be catapulted into the air. The method of catapulting is either by compressed air or an explosive and the effect is, of course, to give the plane flying speed in the course of a few yards, speed which with her engines she could not attain for perhaps a hundred yards. The acceleration is very rapid and

the pilots have to make sure that their backs and necks are well supported so that they are not injured by the force which holds them back because of their inertia.

For the use of a large number of aircraft in a fleet action, it was obvious that some better arrangement was required and Britain pioneered the aircraft carrier, a ship specially designed to carry and despatch aeroplanes. The aircraft carrier is, in essence, a floating aerodrome, the large deck-surface taking the place of the familiar grass or tarmac. Armour and armament are of secondary consideration, the aircraft carrier making it its business to "keep out of trouble". The only armament, generally, is a number of batteries of anti-aircraft guns, to protect the carrier against bombing or torpedo-carrying aeroplanes. In battle the carrier would be well-protected by other warships.

Two aircraft carriers were completed before the end of the last war—the *Furious* and *Argus*—but the absence of major fleet actions prevented either of them being tried out under the actual conditions of battle. The aircraft carrier, indeed, has yet to show its value in active service, although experts are inclined to agree that it may play a decisive part in any future fleet actions. Its own disadvantages are its vulnerability with the fact that battles are often fought under conditions of mist or storm which make landing and taking-off impossible. It is just in such conditions that the fleet particularly needs "eyes" and for this reason it seems certain that the aircraft carrier will not, at any rate for many years, supersede the older forms of scouting by destroyers or light cruisers.

Both the early aircraft carriers were converted

vessels, one had been laid down as a liner and the other as a cruiser. Nevertheless, each had the leading features of the latest aircraft carriers, a long, clear deck for taking-off or landing, considerable speed, hangars below decks for storing the planes and hydraulic lifts for bringing them on deck. The aircraft carrier needs speed for two reasons, first to enable it to keep up with the fleet for it is not a warship that will ever act independently or take part in actions alone and, even more important, to enable it to steam into the wind at such a speed that the relative speed of aeroplane to deck is such as to make take-off and landing easy in a short distance.

It will be realized that an aeroplane must attain a certain speed before it can rise. This is not the speed of the aeroplane over the ground, but relative to the air passing over its wings. Thus an aeroplane facing a 90 m.p.h. wind would attain flying speed almost immediately although it is not likely to attempt taking off under such conditions. The aircraft carrier steams into the wind, a little jet of steam in the bows ensuring that it is always travelling exactly against the wind. Another reason for this is, of course, that the landing-deck although up to 800 feet long, is comparatively narrow and any cross-wind might make landing difficult, if not actually dangerous. The deck itself is marked with three broad white lines to assist the pilots in landing. The first landings are made with comparatively light planes which can be brought up quickly and pilots do not attempt to land with heavier service craft until they have become used to the unusual conditions. The deck is sloped downwards

towards the stern to assist them if they misjudge the distance a little or if the vessel is rising and falling in a swell. To ensure the planes stopping, powerful wires are stretched across the deck which can be raised a foot or two above it when required. A hook on the end of a wire from the aeroplane trails across the deck, catches in one of the wires and after the absorber has "given", brings up the aeroplane short. Many landings are, however, now made without using the arrester wires.

The measurement of distances by the eyes is relative, and many pilots have stated that they find it easier to land on the deck of a carrier with some superstructure at the side than one which has nothing above deck level. The earliest carriers simply had a deck on top, the bridge and superstructure being below deck level in front. Apart from giving a clear landing space, the idea of this was to avoid any dangerous air eddies from the funnels and mast. The tendency recently, however, has been to build carriers with an "island" at the side, the island consisting of funnel, bridge and mast. Streamlining has enabled the air disturbance created by this island to be reduced to a minimum, and apart from the advantages to navigation accruing through having a high observation point, there is that of giving pilots about to light something by which to judge their distance. The first of the carriers to have this "island" was the *Hermes*, and this is also the type of the *Ark Royal*, the latest aircraft carrier to be completed.

The personnel of an aircraft carrier is quite unlike that of any other warship, for apart from sailors or

pilots, she must carry mechanics, fitters and all kinds of specialists. In the hull of the ship, in addition to hangars for some sixty aircraft ranging in type from the fighter to the torpedo-carrying plane, there are completely fitted workshops such as you would find at an ordinary aerodrome. Even the powerful engines have to be specially designed and placed, for the smoke or steam must be carried to vents in the side to prevent their obscuring the view of the airman.

The aircraft from carriers to-day may have a number of specialized tasks to perform. Apart from scouting and "spotting" for the guns, they would be expected to engage enemy aircraft to prevent them carrying out the same duties for their own fleet. The seaplanes carried on board British ships during the last War were able to make it very uncomfortable for Zeppelins engaged in the task of spotting and one was brought down. Then the aircraft are equipped for bombing and torpedo dropping. But it is probably as "the eyes of the fleet" that the aircraft carrier will prove most successful. The confidence of Britain, usually rather slow to adopt new ideas, is shown by the fact that in addition to five aircraft carriers in commission, five more are under construction, giving us a great preponderance of these vessels over the navy of any other power. The United States has larger carriers, taking 80 planes with a number of reserves, but the fact that Britain has an unusually large area to patrol has probably decided the authorities in favour of numbers rather than mere size.

The submarine is another specialized war vessel which has become of great importance through its

use to attack unarmed ships and thus to impose a blockade. Its development was a good deal slower and more difficult than that of the aircraft carrier. The idea of a submersible vessel that could approach its enemy unseen and deliver an attack before its presence was known is very old, but the submarine with any chance of success had to await a number of other inventions. First of all, it needed a suitable power plant. One of the earliest submarines, that of Van Drebel, which is said to have travelled some miles in the Thames under water, was propelled by oars, but the displacement of a submarine vessel is such that this method must have been exceedingly laborious even for a very small ship. No account is given of how the men engaged in rowing were supplied with air.

Until the coming of steam power, the submarine was necessarily merely a dream, and since steam meant vents above the water, even this did not solve the problem. Modern submarines are propelled when submerged by electric motors; thus the submarine had to await the invention of the dynamo and batteries. A number of modern submarines have been steam-propelled on the surface, but this method was never altogether satisfactory and has now been generally abandoned in favour of the internal combustion engine, the Diesel engine being universally used.

The submarine was not really possible until the invention of the screw propeller, paddle propulsion calling for too much power when submerged and being too clumsy. The submarine further required some method of seeing under water and optical science had to progress to the stage where a suitable periscope,

the construction of which has been described, could be built. Then again, the submarine to be of real service, required a weapon that could be fired under water. It had, therefore, to wait until the invention of the torpedo gave it a weapon which was truly effective. It will be seen from this that the submarine makes use of many major inventions and its appearance as a practical vessel towards the end of the nineteenth century was not accidental or due to the particular genius of inventors at this time but rather to the perfection of a number of other ideas.

The one point that distinguishes a submarine from other vessels is that of buoyancy. Whereas the buoyancy of other ships is, comparatively, constant and always above the point required to keep them on the surface of the water, the buoyancy of the submarine can be varied. This was the vital invention that "made" the submarine. The absence of one or other of these inventions was responsible for the comparative lack of success of submarines before 1890. For instance, an American inventor named Bushell built a one-man submarine in 1771 and used it against the British fleet. The screw was hand-propelled and the submarine, lacking anything approaching a torpedo, had to screw a mine to the hull of the ship it was attacking. It was obvious that such a vessel, ingenious as it might be, was of little more service than for attacking ships in harbour and to cause a certain amount of panic. There were many similar inventions during the early part of the nineteenth century but most of these contrived to do no more than drown their crews. Even in 1875, we find John Holland, the American inventor,

building a submarine which one man worked by pedalling a propeller. Nevertheless this submarine carried five torpedoes, and later, Holland submarines were bought by the Admiralty for experimental purposes.

How little the possibilities of the submarine were appreciated, even as recently as 1900, can be seen by a statement made in the House of Commons that the Admiralty did not propose to design one because such a boat would be the weapon of an inferior power. For once it is only fair to say that two years later the Admiralty were ordering submarines. In comparison with the modern submarine it may be stated that they were about 65 feet long, had a crew of seven and a speed of 5 knots under water.

The method by which the buoyancy of a submarine is varied is by the alteration of its weight without alteration of its size. The submarine is not, strictly speaking, heavier than water, but when submerged, of the same weight. We may make a comparison with a piece of wood which floats on the water until such time as it has absorbed so much water that it is roughly of the same specific gravity as the water, or water-logged, when it floats in the water. The relative weight of the submarine is altered by taking in or expelling water ballast contained in special tanks. In the first submarines these tanks were placed at the bottom of the hull, and this form was retained for many years by some designers. It necessitates a circular section, whereas by placing the tanks all round or simply at the sides, a better form can be obtained. A submarine really has two hulls, the inner one of which is known as the

pressure hull. The amount of water ballast carried is regulated by compressed air carried in bottles, which are refilled on the surface. When it is desired to lighten the submarine, compressed air drives out the water in the tanks, "blows them", and the submarine becoming more buoyant, rises. When the vessel has to be made heavier to sink, the compressed air is allowed to escape, water enters the tanks through valves and increases the weight of the submarine.

Tanks have to be emptied and filled not only in accordance with the position it is desired the ship shall take relative to the surface, but also in relation to the consumption of food, fuel and supplies. To maintain the "trim", water must be taken in to compensate for the fuel consumed by the engines. This is done by means of special tanks, the water being admitted automatically. It does not mix with the oil due to the difference in specific gravity. This difference means that rather less water is required by volume than liquid fuel is consumed. The release of a torpedo would also alter the trim of a submarine considerably but for the fact that there is water in the tubes at the moment of release, and more immediately flows in to compensate for the lost weight. Keeping a submarine in trim so that it is always ready for diving is an intricate matter. Whereas it used to take ten to twenty-five minutes for a submarine to dive, one or two minutes are now sufficient, a matter of some importance upon which the lives of the crew may depend in war-time.

Normally, a submarine dives by reducing its buoyancy, but not to the point where it sinks straight down, and then moving its horizontal rudders so that a

forward motion drives it downwards. When the desired depth is attained the horizontal rudders are "straightened" so that, if the trim is maintained, the submarine continues at the same distance below the surface. To rise, the tanks are blown and the horizontal rudders moved upwards until the submarine breaks surface. The horizontal rudders, or "hydroplanes", guide the submarine in the vertical plane, an ordinary rudder being used, of course, for control in the horizontal plane. The hydroplanes, a confusing term, are fixed both in bow and stern.

A submarine may, in an emergency, do a "crash dive" in which tanks are suddenly blown and the downward movement is due to the great increase in weight as much as the hydroplanes. The danger is that the dive may not be checked and the submarine might strike its nose on the bottom.

The depth to which a submarine can descend is limited by the strength of its pressure hull. Beyond a certain point, the weight or pressure of the water is such that it bends the plates and causes a leak. When the submarine wishes to observe what is going on, its depth is limited by the length of its periscope, usually about 30 feet. Space and weight are all-important in the submarine and therefore it is not usually made stronger than for depths to which it might normally be expected to descend. Another feature of submarine construction is the division of the vessel by bulkheads with doors which can be rapidly closed. These doors are strong, so that they can withstand the pressure of the water. Thus in the event of an accident holing the submarine and admitting water, the part affected can

be shut off and the crew remain safe in other compartments.

Although the submarines of to-day, displacing between 1,000 and 2,700 tons, are incomparably stronger, faster and more seaworthy than those of pre-war days, they remain as vessels with considerable limitations and great vulnerability. The speed and the length of time for which they can cruise under the surface depends upon batteries which have to be re-charged when running on the surface with the Diesel engines. The consumption of electricity from the batteries varies as the cube of the speed so that it will be seen the time that a submarine can remain submerged at full speed is comparatively short. The batteries themselves add to a submarine's vulnerability. If sea-water is admitted, the sulphuric acid may produce chlorine and sodium sulphate, while if the batteries are run down to the stage where they begin to charge, hydrogen may be given off, forming an explosive mixture with the air.

The great vulnerability of submarines has led to many disasters and the invention of various devices to enable those trapped in a sunken submarine to escape. These devices are primarily only of use in peace-time. It may be expected that in war-time a submarine will be sunk by gunfire, depth charges, or bombs in such a way that water will enter all compartments and make the chance of escape very slender.

Two chief devices are used for escape from a submarine and both are concerned in the principal difficulty, the equalization of pressure inside and outside the submarine. Escape by simply pushing open a

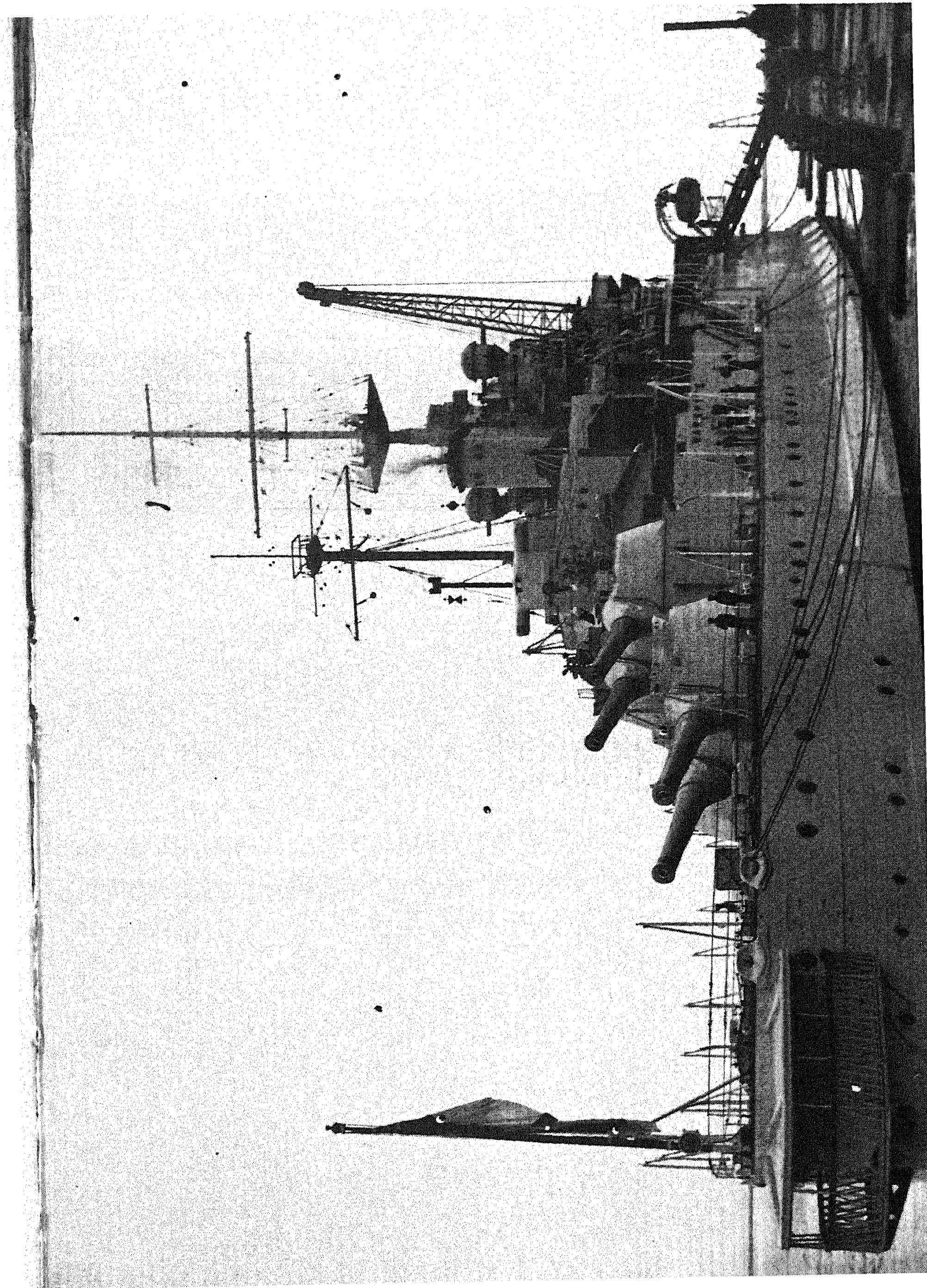
hatch and pushing upwards is impossible, even when the submarine is in comparatively shallow water, because of the weight of the water on the hatch. In the Davis escape-chamber, valves and pumping apparatus are provided which enable the men escaping to enter the chamber when it is empty, then to flood it so that pressure is equalized with that outside, when a hatch at the top is more easily opened and the men can float to the surface. Each man is provided with a special apparatus which provides him with oxygen to breathe while making his way upwards and a lifebelt to keep him afloat until he is rescued.

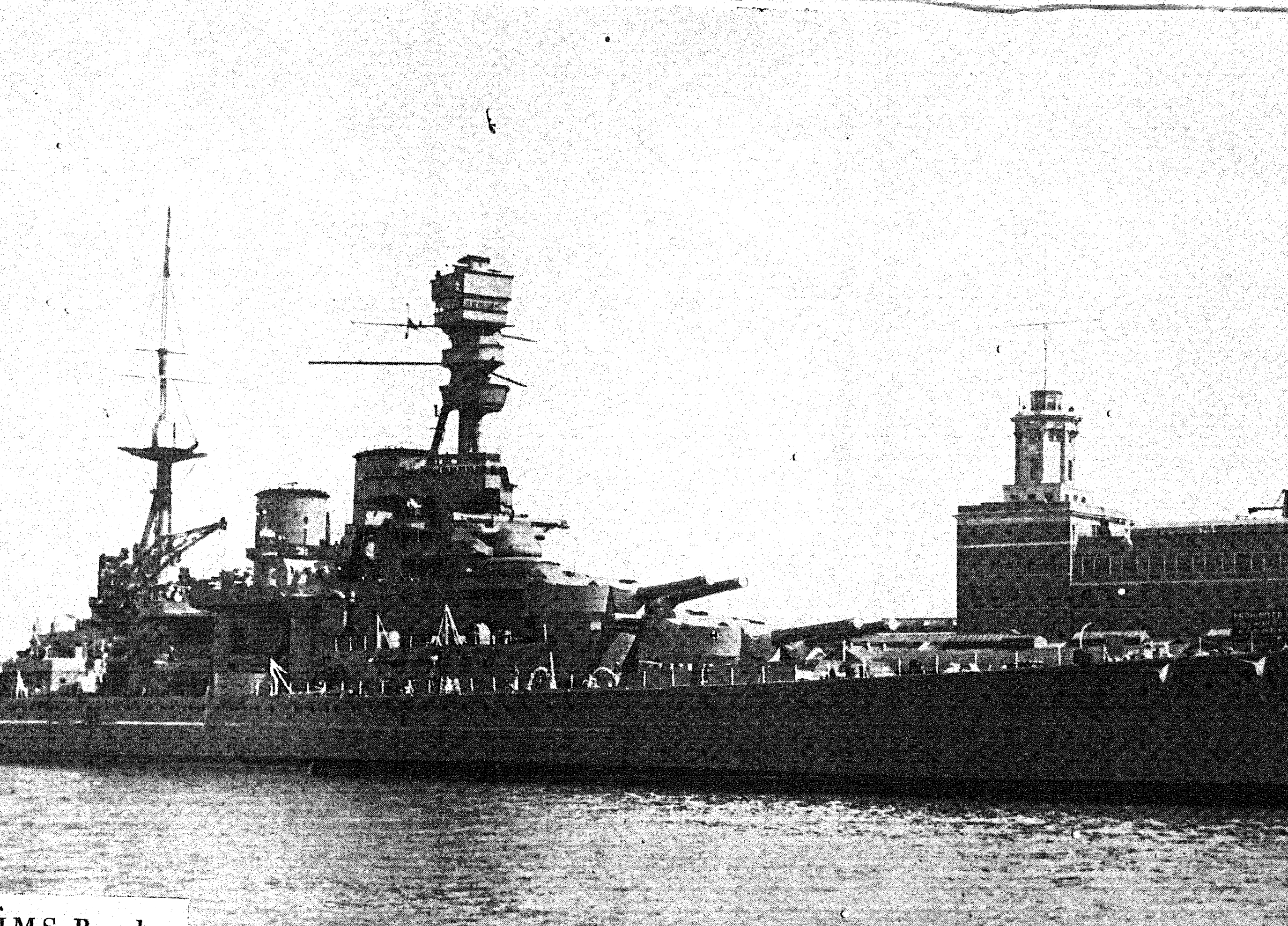
Another system which the Americans have adopted is that of a diving bell which is fastened over a special hatch in the submarine, making a watertight joint, the water being kept out by compressing the air. The hatch is then opened and men are able to escape a few at a time as the bell is closed and brought to the surface again. One of the difficulties experienced is that when the operations are carried out at considerable depths, the men are subjected to high pressure and, unless they are taken to the surface very slowly, with long pauses, may get the "bends". This is a painful and dangerous disease due to bubbles of nitrogen dissolved in the blood under pressure being released and pressing upon the nerves or entering the heart. Recently it has been found that the inert gas helium is not so soluble in the blood and that if this is substituted for nitrogen in the atmosphere provided to breathe, the ascent can be made much more quickly, or alternatively the men can stay at greater depths for longer periods in perfect safety.

Both these methods have much to recommend them as well as their own disadvantages. The Davis apparatus requires special training, considerable nerve, and may be difficult for use by men exhausted by breathing poor air. The diving bell device necessitates the location of the sunken submarine by special ships which may be many miles from the scene at the time of the disaster, and a number of trips to rescue the large personnel of a modern submarine which itself may be tilted at a very awkward angle.

Undoubtedly scientists will continue to exercise their ingenuity in endeavouring to lessen the dangers of this, the most vulnerable type of warship. Smoke buoys to indicate the position of a submarine can now be released, also buoys making possible telephonic communication. A buoy has been invented that releases a large amount of dye which, spreading over the water, should be easily spotted by aircraft. There seems no reason why an air pipe should not be released in an emergency so that those trapped in a submarine are assured of their most vital need in staying alive: oxygen. But many devices which work perfectly in the laboratory cannot stand up to the very trying conditions often found at sea on active service and the submarine is always likely to remain a most dangerous ship when it is in difficulties. The disasters which have marred its history should not, however, blind us to the fact that thousands of dives are made and millions of miles covered without any mishap.

Britain has once offered to abolish the submarine as a weapon of war, but her offers have been rejected. Except for one brief period during the war when un-





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restricted attacks upon merchant vessels were in danger of starving out Britain, the submarine has never lived up to its reputation as a menace. In future wars it is likely to be even less dangerous owing to the great improvement in anti-submarine measures, not only offensive, some of which have been described, but defensive, notably the convoy system and aeroplane patrol. Very few ships in convoy have been successively torpedoed when accompanied by aircraft. The mere knowledge that aircraft are about is apt to send the submarine down, for it knows that it cannot hide from an aeroplane other than at a considerable depth. The British Admiralty were partly right in 1900 when they said the submarine must always be the weapon of a weaker nation. For this reason it is likely to remain popular, not necessarily because of the damage it can inflict, but because of the dislocation it can cause by its constant threat.

CHAPTER X

MINES AND TORPEDOES

THE TORPEDO and the mine, the only weapons that can sink a modern ship with a single hit, because they strike below the water-line, evolved together. The earliest type, which to-day we should class as mines, were called torpedoes. Later, moving charges which represented the beginnings of the modern torpedo, were called mines. To-day the difference is clear. A mine is a vessel containing a charge of high explosive which is usually exploded when the hull of a ship strikes it. It may also be fired by radio or by a time device. The mine may be on, or just below, the surface. A torpedo is mobile and moves towards its target. It strikes deliberately and not almost accidentally, like the mine.

It is rather ironic that the torpedo, now a very formidable weapon at sea, when first invented should have been refused by the French on the grounds that it was a weapon unfit for a civilized country to employ. Pitt, the English Prime Minister, was blamed by many for toying with the "first refusal" of the weapon on the grounds that it was likely to lead to the destruction of British sea-power, making it impossible for capital ships to exist. As with every offensive weapon, the

first estimates of its potency were greatly exaggerated. It was not for many decades that the torpedo, or for that matter, the mine, became a really effective weapon. Methods were soon found of circumventing both devices to a considerable extent. It is interesting to note that more than a hundred years after Pitt, the torpedo did, very nearly, prove the undoing of British sea-power by its unrestricted use against merchant vessels.

But the torpedo used by modern ships and submarines is a very different thing from the torpedo invented by Robert Fulton, more famous as one of the pioneers of steamships. Fulton's torpedoes were little more than floating mines, fitted with time or percussion fuses so that they could be drifted down-current against an enemy vessel where they would explode. They suffered from many defects. Only gunpowder was available to fill them so that a large charge had to be carried. There was great uncertainty about the direction they would take and therefore they were really only suitable for use against a fleet at anchor. Indeed, Pitt's interest seems to have been limited to employing them to destroy the armada which Napoleon had assembled for the invasion of England. This fleet would not come out to fight; the British Fleet could not get into the harbour and tackle them on the spot. A number of torpedoes seem to have been released against this fleet, but with little damage resulting. It seems that the British officers disapproved of the weapon almost as much as the French. War was still partly a game, to be played with certain rules, and the use of an underwater weapon appeared unsporting in those days.

Floating charges which exploded when they struck a ship developed into the mines which play a most important part in modern warfare. The desire to have an underwater method of attack that could be more deliberately aimed led to all kinds of experiments. Most of them came down to the employment of human beings to run a charge of explosive against the side of a ship, light a fuse, and make their escape. In some cases there were quite ingenious ideas for causing the fuse to light itself upon striking a solid object; the essential idea being to strike below the waterline where damage would be specially serious.

During the American Civil War "torpedoes" were used. These consisted of an explosive charge tied to the end of a long pole carried over the bows of a small rowing-boat. The boat drifted or was rowed, of course at night, towards the enemy vessel. When it reached it, the pole was dipped under water and fired. One warship was sunk in this way, but this crude torpedo was obviously impracticable; it was almost certain death for the man in the boat. The development of flares and searchlights meant that, even at night, the torpedo had little chance of getting close to the target before being blown up by small guns.

It is interesting to note that once again we have reverted to the old idea; small, powerful, motor-boats carrying torpedoes right up to the enemy are among the latest methods of naval warfare. The Japanese are even said to have torpedoes containing a helmsman who steers the missile so that a miss is impossible, making his escape through a hatch at the last moment. Actually, such a weapon seems almost impossible. Being of

the necessary size to carry man, explosive and viewer, its wake would be as plainly discernible than that of a 21-inch torpedo; it would very likely be destroyed long before it reached an armed ship. One must put down "news" of this and similar weapons calling for the almost certain destruction of their users, to part of a carefully thought out campaign designed to impress with the "do or die" spirit.

The invention of the electric motor opened up new possibilities, but storage batteries were too heavy to be employed and the first electric torpedo was fed with power to drive its propeller through a wire which was unwound behind. Mechanical power devices were also tested. Although this weapon was at one time actually used by the British, it was obviously clumsy, and the necessity for carrying huge storage batteries made it impossible to fire from a ship at sea. Nevertheless the incorporation of a propeller, which was only invented one hundred years ago, was a step towards the modern torpedo. Another torpedo depended for its power on the momentum imparted to a heavy fly-wheel before it was launched. You can see children at the seaside with model submarines working on this principle; yesterday's newest weapon being to-day's toy. The child turns a handle outside the submarine very rapidly. This rotates a heavy wheel inside connected to the propeller. When the submarine is placed in the water, the propellers continue to be turned by the fly-wheel for a surprising length of time, the great fly-wheel weight giving a considerable amount of stored energy. In the Howell torpedo the momentum before launching was imparted by a steam-engine.

The modern torpedo began when Robert Whitehead developed the ideas of an Austrian naval officer who had consulted him. The essentially new departures of the Whitehead device were the employment of compressed air as the motive power and of a water valve with pendulum weight to keep the torpedo at a constant depth. The first torpedo, made in 1864, developed a speed of only six knots, for a short time, but from this we have reached the modern torpedo with its speed of 40 knots or more and a range of over three miles. Improvements have nearly all related to increasing the efficiency of the engine so that the torpedo could be increased in size and improved in speed. The one essential added was the gyroscope to ensure that direction was maintained.

At first, torpedoes were "fired" by their being allowed to slide into the water in the direction required, but obviously this did not make for accurate aiming. To-day, they are fired from tubes either by compressed air or by the gas from cordite. In the case of discharge from a submarine, the tube has to be fitted with a water-tight door which is closed before the torpedo can be inserted from inside. The inside door is then closed, the outside door opened, and the torpedo discharged by compressed air without water getting into the submarine.

A little trigger on the torpedo is caught as it moves forward in the tube; this starts the engine working and the gyroscope revolving. The engine draws its motive power from fuel and air burned in a generator. There are various devices for regulating its speed and compensating for the reduced pressure as the air is used up.

Two propellers moving in opposite directions are fitted, compensating each other for any tendency to drag on one side. The movements of the pendulum weight, with a valve, regulate horizontal rudders so that the torpedo takes up and remains at a certain depth.

The vertical rudder is controlled by the gyroscope which is set in motion by the release of a powerful spring when the torpedo is fired. It controls the direction of the torpedo through its gyroscopic action tending to maintain its direction in space. Thus, if the torpedo deviates from its setting, the gyroscope acts on the vertical rudder until the deviation is corrected. If necessary it can be arranged for the torpedo to travel in a curve by setting the gyroscope at an angle. The device is very similar to that used for the "automatic helmsman" on large liners only that different methods of maintaining the gyro are employed.

A torpedo fired at a target a mile away will require about 1½ minutes to reach it. During this time the ship will have travelled, perhaps, half a mile, if it is travelling at speed or a quarter of a mile if it is proceeding slowly. It is therefore useless to aim a torpedo exactly at a ship. It must be aimed at a position which the ship will occupy when the torpedo arrives. This calls for calculation of the ship's direction and speed. Of course, the nearer the target, the greater the chances of hitting; but with above-water craft the torpedo can be seen when it is fired and this often gives time to change the course of the ship so that it passes astern or ahead.

When torpedoes were first brought to some perfection they caused considerable alarm to those who had been building huge battleships. Here was a weapon

with which a small torpedo boat could sink a battleship in a few moments. The reply was destroyers to protect battleships from torpedo boats, but very soon these destroyers themselves became users of the torpedo. Then there were steel nets hung on booms from the battleship, so that the torpedo was caught before it touched the side. Torpedoes were fitted with wire-cutting devices in their heads, to get through these nets; but in the end the nets, because of the reduction in speed they caused, were soon discarded. The battleship has now come to rely, first of all upon a protecting screen of destroyers, then upon numerous water-tight compartments to minimize the damage done in the event of being struck, and upon a keen look-out to spot the approaching torpedo.

The torpedo gives itself away because of the stream of bubbles of waste gas which marks its track. In calm water these can be seen quite clearly at some distance and many ships have saved themselves by a prompt helmsman. Not long ago it was reported that an Italian engineer had succeeded in constructing a torpedo which used only gases that were soluble in water so that no tell-tale bubbles appeared. If this, in fact, has been perfected, the torpedo has become a deadlier weapon which no longer gives warning of its approach; but as the gas reported to be released was ammonia, it is not certain that this substance is particularly efficient, from the aspect of convenient power in comparison with the older method.

The greatest development of the last War in connection with torpedoes was their discharge by aeroplanes. First experiments were made with the torpedo-plane

as early as 1912, but as a modern torpedo weighs about half-a-ton, it was obvious that this weapon would have to await improvements in the carrying ability of aircraft. The principle is quite simple. The aeroplane, or more generally seaplane, carries the torpedo in its undercarriage and a simple release mechanism enables it to be "fired" when the aircraft is only a few feet above the water. Actually, no firing is required, the forward movement of the aircraft itself taking the place of the compressed air from a tube. The torpedo plane is to-day a formidable weapon, although how dangerous under war conditions remains to be tested. The matter has already been discussed in its relation to battleships; these torpedoes, carrying between 300 and 400 pounds of high explosive, are usually launched at a height of between 20 or 50 feet.

Some time ago it was reported that the Italians had devised a new method of using torpedoes. Instead of being aimed directly at a target, it was released by means of a parachute over a fleet, preferably one at anchor in harbour. On striking the water, the parachute was automatically cut loose and the torpedo, with its rudder permanently set, began running round in circles until it struck a target. This sounds an effective and demoralizing weapon for use in special circumstances, but I fancy it would not work out so well in practice, for if we draw a diagram to scale showing ships in harbour, it is surprising to see how much room there is for a torpedo to describe circles without striking anything at all. Further, the slow descent of the torpedo by parachute would not only call for some accuracy in gauging the wind drift, but also make the missile a fairly

easy target for small guns so that it could be cut loose from its parachute prematurely and dive to destruction. The mere experiment with such a weapon suggests that those responsible for torpedo-planes do not anticipate that close approach to warships will be easy.

Many experiments have been conducted with a view to guiding a torpedo by wireless so that however the target-ship may twist and turn, the torpedo could follow it and eventually strike. The principles of direct radio control are fairly simple, a series of signal actuating relays connected to a small motor working the rudders or gyroscopes. But the prevention of interference by other signals is quite another matter. Power cannot be transmitted and the balanced interlocking gear which controls the localized power units by radio is most complicated, real selectivity or secrecy cannot yet be said to have been attained under practical conditions. In the case of a torpedo, only two movements are required; those of the vertical rudder, for there is no need to alter the depth at which the torpedo travels. The difficulties of radio-signalling underwater are considerable, especially when it is remembered that a torpedo must be fairly robust to withstand the shock of entering the sea. The use of sound waves has also been tested; while the provision of a small mast can help with the reception of control signals but is very liable to cause a mark which is quite visible.

An interesting device was patented some time ago in which the torpedo was attracted to the side of the target-ship by means of a magnetic balance. This balance was automatically brought into action after the torpedo had travelled a certain distance, beyond the target. A

large mass of metal, such as a ship's hull, acting on the magnetic balance, would cause it to operate the controlling motors so that the torpedo was turned and approached the ship from the opposite side. Like so many new weapons of war this may be theoretically perfect. But to avoid complications, the torpedo would obviously have to swing in a fairly wide arc and this would give the ship the opportunity to change course once more. Moreover, the weapon might be dangerous in an action, for there is the possibility of attraction by the wrong ship.

The most dangerous use of the torpedo, developed since the Great War, is perhaps, its employment by small high speed motor-craft. Several raids with these ships were made towards the end of the War, notably by the British against the Bolshevik fleet in the Baltic. The motor-boats, with a speed up to 50 m.p.h., travel at full speed towards the enemy fleet, release their torpedoes, and turn rapidly. This is really a development of the torpedo attack by destroyers, with the difference that the motor-boats are comparatively small and fast so that they offer a very difficult target to the battleships being attacked. A raid of this type is most likely to be successful in closed waters, since the motor-boats cannot be expected to keep the sea in rough weather. It would probably have to be made under cover of darkness; even then, against a well-armed ship, there may be a considerable chance that the motor-boats will be put out of action by the rapid and concentrated fire of small guns.

At present, technical opinion suggests that these and other possible developments are an indication that the

torpedo has very definite limitations. The destruction worked by the torpedo against battleships during the Great War was comparatively small, although some 1,200 merchantmen were sunk in this way. In future hostilities it may prove a comparatively ineffective weapon against fast and well-armed ships, especially now that three or four torpedoes are often required to put a battleship out of action.

To revert to the mines from which the torpedo developed. Mines were used in the Crimean War by the Russians without any marked success, except that they caused a diversion. The British and French fleets evolved a method of sweeping for the mines which is still used and which caught several score. In those days, mines were constructed of wood like barrels, or with a thin copper sheeting, and were filled with gunpowder. They were fired when large projecting bolts were struck by a vessel, nearly every mine being moored to the bottom.

The distinction between the fixed or floating charge of explosive and the charge which was carried to the enemy by a mechanically-propelled device, was made some seventy years ago. The mine developed along the lines of the electrically-controlled torpedo and was used chiefly for the defence of harbours. Lines of mines were laid across the harbour entrance and connected by wire to the shore so that any particular mines or the entire float could be blown up by the touch of a switch when an enemy ship was seen to cross the line.

To avoid the possibility of attacking ships creeping through a mine field in fog, mines were arranged so that when one was touched, a circuit closed and the

explosive was discharged. A master-switch on shore could be opened to make the mine field harmless when friendly ships were passing. Mines were used and did considerable damage in the Russo-Japanese War, but it was not until the Great War that the use of non-controlled mines was fully developed.

The importance of mines in 1914-18 can be gauged from the fact that about 170,000 were laid in Northern waters by the Allies. To these must be added the number set in the Mediterranean and those used by the Germans. In fact, the British and Americans completely closed the northern entrance to the North Sea by a barrage of mines laid from the Orkneys to Scandinavia.

The essential of an uncontrolled mine is that when laid it shall take up a certain position in the water and maintain its bearings. The mine, when laid, sinks to the bottom of the sea with its sinker and, after an interval of time to allow for the safe passage of the ship releasing it or accompanying ships, it is released so that it extends to the end of its wire rope, the length of this rope in relation to the depth deciding how far below the surface the mine will float. British mines used to be laid on the surface, a small weight attached to a cord equal in length to the decided depth of the mine pulling down the mooring rope until it touched bottom. The mooring rope then stopped unwinding and the mine floated at the correct depth. This simple but ingenious plan was not found altogether satisfactory and later mines on the German principle were used.

The depth at which a mine is set depends upon the draught of its intended victims, the tide and other

factors. When there are strong tides, the mine is only dangerous for a short period, being either too high or too low for most of the 12 hours. The mine is fired by means of a number of projections corresponding to the nose of a shell. When one of these is struck, the mine is detonated, a starting charge of gunpowder being sometimes required. To increase the effective area of a mine, the Americans made them with *antennae* which extended for some ten yards and fired the mine electrically when touched by any metal.

By the rules of war, a mine should contain a device for making it inoperative if it comes adrift. A floating mine is a menace to friend, foe and neutral alike. But this rule was, like so many other old-fashioned ideas, honoured in the breach and, in fact, the floating mine became a weapon. Obviously floating mines are a weapon of the weaker side, since it is as dangerous to friend as to foe, but dropped by a retreating fleet, they may discourage pursuit, if they do no actual damage. Floating mines have been developed which keep a constant depth by water pressure. As soon as the mine sinks beyond a certain depth the pressure operates a valve which sets a propeller into motion, driving it upwards. It is interesting to note that this device is used by a species of minute water life which is thus able to keep always at a certain distance below the surface.

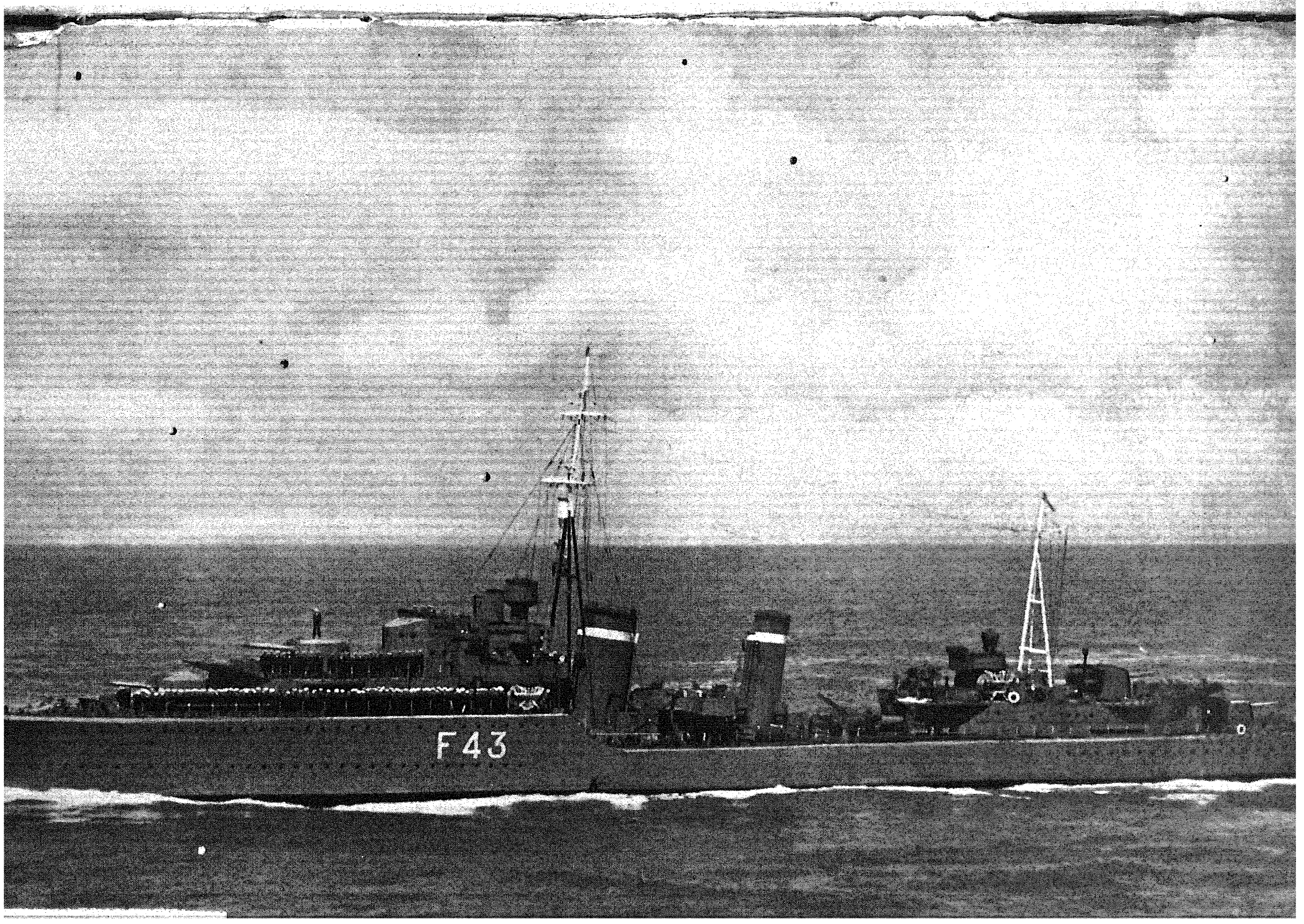
As with every other weapon, there is a defence to the mine. The first reply was sweeping; nowadays mine-sweepers would play an essential part in any defensive system. Two ships carrying a wire between them sweep up the mine, which is then destroyed. "Explosive" wire-cutters on the sweep may simplify this task. Dur-

ing the War a great number of trawlers were adapted to the work, but in order to sweep fast, as for example, in front of a fleet, special vessels are required. One of the inventions of the Great War was the paravane, designed for special defences against the mine. This consisted of an apparatus, rather like a steel aeroplane in appearance, which when towed through the water by a ship, swung out from its side. Two paravanes attached to wires in the front of the vessel formed a V-shaped protective wedge round the ship, any under-water obstruction being caught on the wires where it was slipped along until it met the paravane and was ready to be destroyed.

In the case of mines, a wire-cutting device in the nose of the paravane can cut them loose and bring them up to be burst or rendered innocuous. The paravane is kept to a constant depth by a hydro-static valve working on horizontal rudders and is generally designed to sweep through the sea a few feet below the maximum draught of the towing vessel. A mercury oscillator is used to correct errors that occur when the paravane is towed at high speed. Many hundreds of ships were equipped with this device by the end of the War; it gives reasonably good protection from anchored mines, except in special circumstances such as when a very long ship is making a sharp turn.

The paravane can also be used against submarines and in this case the paravane is usually loaded with high explosive. On the wire striking a submarine it slips along until the paravane is reached, when the explosive is fired by a contact fuse. There are alternate methods of exploding the paravane, either electrically through the

connecting wire or by the increase of load experienced when the wire is caught up. To prevent any danger of the paravane exploding near the ship using it, a safety device is employed which makes the paravane harmless when towed at a slow speed, in other words, until its wires have swung out into a wide V. With the help of radio detection and other technical methods the art of defence in naval warfare has reached an exceptional degree of efficiency.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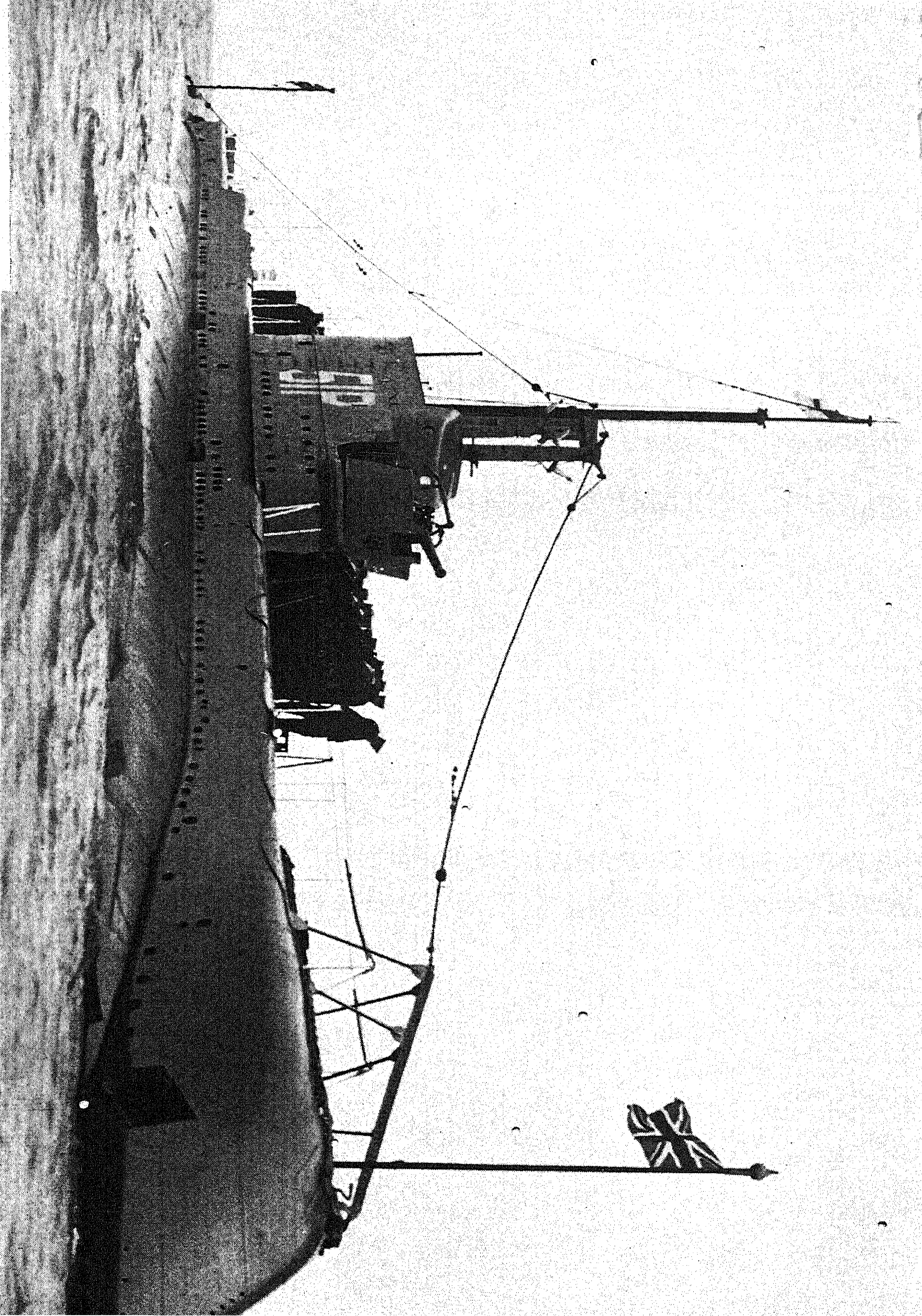


CHAPTER XI

TANKS

DURING THE YEARS that have passed since the European War all the great military Powers have been busy mechanizing their land forces. This has involved not only converting cavalry into tanks, but motorizing all forms of transport. The change has been the greatest that has taken place in armies since men first took to fighting on horseback. From many points of view, even the introduction of explosives did not produce such far-reaching results, since the early guns had much the same range as the bow and arrow. It would not be possible to describe in any detail one-tenth of the numerous mechanized vehicles and fighting machines which are now part of an army. The vehicles are used for every purpose, from the transport of troops and their material supplies along roads or over country, to scouting or actual fighting with infantry. The horse or the mule still have an important part to play in any war, but in the anticipated conditions of a major war, motor vehicles of many different types will perform most of the tasks formerly assigned to animals and, in addition, take part in the actual fighting.

The idea of fighting from moving vehicles is very old, the first machines being horse-drawn chariots, sometimes equipped with knives on the wheels which revolved and mowed down any soldiers nearby. Other more or less mobile vehicles, propelled by horse or human beings, were developed for special purposes, but the coming of gunpowder put an end to their development since they had to be built of wood for the sake of lightness, and the bullet with its greater penetrative power required iron as a protection. Armour was impracticable on vehicles because of the limited weight which could be drawn by horses.

From the invention of gunpowder to the twentieth century there was a complete gap of any noteworthy advance in fighting vehicles. Steam power did not seem to offer any practical possibilities but the coming of the internal combustion engine brought the day of armoured cars, for the power required could be obtained from a small engine. But the armoured car which, essentially, was simply an ordinary car with protective steel plates and loopholes for firing, was vulnerable in its tyres if they were pneumatic, far too slow if they were solid. Moreover, it could only travel on good roads and had few advantages, except for limited purposes, over cavalry. Armoured cars were not built in any great numbers prior to the War. As far as the rapid transport of troops was concerned, none of the nations seem to have realized the value of the motor-car for in 1914 the methods of military transport were still the same as they had been for seventy years: train to railhead and then "footslogging", with horses drawing the vehicles and guns.

Emergency transport was provided in the early stages of the Great War with motor buses and even taxis. Later, when trench warfare had begun, the state of the ground rendered motor vehicles of little use for transport near the front lines, even if they had been available in large quantities.

Interest in the possibilities of an armoured fighting vehicle was revived with the commencement of trench warfare because of the great losses experienced by infantrymen in attacking entrenched positions, even when those positions had been heavily shelled. Machine-gunners were able to take refuge in deep dugouts, emerge when the shelling lifted and then use their guns with devastating effect on the advancing infantry. Some mobile fighting machine seemed to be essential for destroying the "machine-gun nests". No wheeled vehicle could operate near the shell-pitted front lines, but the caterpillar which had been invented by Holt in 1907 for farm tractors, seemed to offer possibilities. Here was a method of transport which was designed for rough ground and would carry a heavy vehicle over mud or other obstacles. The French were struck with the idea of a caterpillar-propelled armoured vehicle when watching Holt tractors at work pulling heavy guns. In Britain, the idea of the tank occurred to Lt.-Col. E. D. Swinton as early as October 1914, almost two years before the first vehicles went into action, and as the idea was inspired by a tactical necessity, he also worked out the correct way of using these vehicles.

It is not necessary here to trace the somewhat tortuous story of the tank in its early stages. Generals

were still thinking in terms of the Boer War, or even the Franco-Prussian war, and the cavalry were being hopefully kept in readiness to break through a gap in accordance with the time-honoured rules. It seems to have been 1916 before the Staff were really prepared to admit that the old moves were impossible against modern defensive weapons and I believe that some of them still hoped for cavalry with "open warfare" as late as 1918. It is only fair to state that the Western Front presented the first occasion on which two armies faced each other along an unbroken line extending from the sea to neutral territory, so that the "flanks" which had been the basis of all military strategy virtually did not exist and a frontal assault was necessary. It was this need that produced the idea of the tank, but the lack of enthusiasm did not give engineers, who ultimately had to do the work, the support they deserved. Archaic prejudice was present to an almost criminal extent.

The name *tank*, by the way, has no bearing whatever on the construction of the weapon but was simply the name given to it during the early stages in order to preserve secrecy. The name "stuck" and a word used purely as a blind to deceive an enemy has entered the language as the name of any armoured vehicle driven by caterpillar tracks. Much the same reason caused the first aeroplanes controlled by radio to be known as aerial targets. Thanks to General Caddell and the late Sir David Henderson, this later invention was encouraged from its earliest stage.

The first experimental plans for a tank really only amounted to putting an armoured cabin on a tractor

and the vehicle was not very successful, particularly in its ability to cover rough ground. A great step forward was the invention of the rhomboidal shape by Lt. W. G. Wilson. This enabled the tank to surmount considerable obstacles and it was used in all subsequent tanks throughout the War. The first tanks were steered by altering the speeds on the two tracks by means of gears and, in addition to the driver, a man was required for each gear for this purpose. Later they were eliminated and the tank was steered by one man by means of an epicyclic gear. The speed of the first tanks was about 4 m.p.h., and their range with the fuel they carried, limited to ten or twelve miles. The first tank to pass its tests was ready in January 1916, fifteen months after the idea had been put forward. It might never have been built but for the persistency of some who foresaw its possibilities. Two types were subsequently built in small numbers, differing only in their armament, one carrying 2 six-pounder guns and the other 4 machine-guns.

The idea of the originator of the tank had been to keep it as a surprise weapon and then to use it in great numbers along a wide front. Whether this plan would, if it had been tried, have ended the War, is open to argument. Casualties due to rough going were heavy amongst the first tanks. But the plan was never tested; perhaps the British lost the opportunity of springing a decisive surprise in the same way as did the Germans with their limited use of poison gas.

The original idea of the surprise attack by tanks was spoiled by insistence on artillery preparation, which further had the effect of churning up the ground so

that the tanks were bogged. It was not until the Battle of Cambrai in the following year that tanks were used, correctly, in large numbers and although they were no longer a surprise weapon, the effect was devastating, the infantry against them either running or surrendering. The attack went forward nearly seven miles, an astonishing amount at a time when people had come to look upon the taking of 700 yards as a great victory.

It is worth noting that this was accomplished after the Germans had had ample time to prepare anti-tank weapons and traps. It is possible that the early failures of the tank had led them not to take it very seriously. In any case, they did not attempt to build tanks themselves until the end of the War, and their great inferiority was an indication of the tremendous asset Britain had in her motor engineers.

The tank continued to be largely misused, although the astonishing success of eleven tank battalions employed in the Battle of Amiens paved the way to the final victory. In the final stages of the Great War tanks played an important part in every action.

I mention these points of history because the whole story of the tank in the Great War demonstrates how the finest military invention can be wasted by a failure to realize the changes in tactics and strategy which it makes necessary. In passing, I might note that the comparison with the German failure to utilize poison gas might be carried further. German chemists discovered the most effective poison gas introduced in the War, mustard gas. But it was the people at whom it was fired and not the commanders firing it, who first realized its value in making an area untenable because

of the persistent character of this particular poison.

One would like to think that the British, who were almost entirely responsible for the tank, have learned their lesson and that when the next important weapon is devised by scientists they will not automatically distrust it or use it without imagination, because it does not appear in text-books of military history.

The tank in use during 1918 was very different from the Mark I type used for the first time on the Somme in 1916. The use of armour-piercing bullets against tanks was anticipated in constructing later tanks and the thickness of armour considerably increased. The first tanks were constructed so as to be capable of crossing a trench 10 feet wide, but this was found to be insufficient. In the fourth type of tank produced a beam was carried which could be loosened from the interior and used to help a tank across a very wide trench. In further types the tank was made longer for the same purpose and more powerful engines installed. The slow speed of the tank had been a handicap in some actions and another type of lighter tank, the original "whippet", was produced, with lighter armour but far greater mobility. By 1918 the importance of tanks had been really appreciated and if the War had continued by another few months an overwhelming number of improved high-speed tanks would have been available to the Allies.

In Great Britain, the story of the tank since the War has been one of apparent hesitation and reluctance to accept this weapon at its face value. But a kindlier view would be to say that it was realized that the tank was revolutionizing warfare and those responsible

were rather puzzled about the best types to use or the method of employing them to best advantage. For a period, development was largely limited to the production of a few units of improved types and experimenting with them in manœuvres. It is only recently that the mechanization of the army and the production of tanks in large numbers has begun. This may be all to the good. The military authorities naturally desire to have as many up-to-date tanks as possible and it was impossible to decide on the relative proportion of the various types until the ways in which they were to be used had been decided.

The first tendency seems to have been towards the "super tank", the equivalent of the *Dreadnought* at sea which would be able to maintain its superiority by sheer weight of armour and gun power. The analogy with the sea does not really run, since a single shell from a concealed position may put the tank out of action before it can locate and destroy the attacking gun. At sea, the big ship has a greater range for its guns and is able to fire on smaller ships while they are powerless to reply. The pendulum then seems to have swung towards the light tank, the real equivalent of cavalry on wheels. A one-man tank of great mobility was produced and later converted to a two-man tank, with one soldier steering while the other fired, the tank relying on great speed, up to 40 m.p.h. or more, to avoid destruction, rather than upon thickness of armour.

Whatever the military have demanded, engineers have produced. The tendency of design has been rather away from the rhomboidal shape and this is much less pronounced in the modern heavy tank which

has a gun turret surmounting a comparatively low body. In the very light tank, really an armoured machine-gun carrier, there may be wheels as well as tracks, enabling great speed to be attained on level ground. At the present time, tanks may be divided into three classes. First of all there are the very light tanks, the equivalent of cavalry. Then there are the mixed tanks, fighting as a brigade, and finally the tanks for infantry co-operation, performing the tasks given to the first tanks used in the Great War.

It is certain that the tank in the next war will not have the "walk over" it enjoyed towards the end of 1918. Defence against the tank in the Great War was provided by armour-piercing bullets, traps, mines and field guns. In future wars the tanks will undoubtedly have to face other tanks and it may be expected that duels will take place between large tanks. In addition, other protective measures have vastly improved. Tank mines were not very successful in the Great War and the digging of traps in the front lines involved great labour at considerable danger. But during the years of peace there have been ample opportunities for the preparation of traps and mines along the frontiers. Moreover, mile after mile of iron railings fixed in concrete at an angle, form an obstacle that tanks cannot easily climb or knock down. The power of armour-piercing bullets has improved. Towards the end of the war the Germans were making a 13-mm. machine-gun capable of firing a bullet which would penetrate about half an inch of armour. More recently the British have developed a small armour-piercing shell which does not explode until it is inside the

tank. The Germans are said to have developed a similar shell containing thermit, the ignition of which inside a tank would make it untenable.

As far as can be judged from the wars fought during recent years the tank is no longer so formidable in attacking infantry in well-defended positions and is becoming very vulnerable to armour-piercing bullets. I doubt whether the ponderous "land battleship" will prove effective against a well-armed enemy and it is probable that the tank employed will be chiefly of the light type, capable of great speed and performing the tasks formerly given to horsemen, including scouting. The only conditions in which the heavy tank might be decisive is in trench warfare, and the exact conditions of the Great War are not likely to be repeated.

Of great importance has been the development of light wireless transmitters and receivers which enable a large number of tanks to keep in touch with their commander. The tank is no longer an individual unit going into battle as a "free lance" or at best in some sort of line maintained by visual observation. The full significance of this change has nowhere been better realized than in Britain.

The great danger with a weapon of the tank class is to work on the assumption that the conditions in which it will be used will be similar to those in which it was used ten or twenty years before. Every war produces its particular problems or new conditions and that is why, apart from the control of fear, imagination may be more useful to a modern soldier than knowledge of the drill book. I have said some unkind things about Victorian generals, which should,

of course, be taken to refer not to particular examples but to the involutions of the "army mind" in sharp distinction to the progressive attitude of many other departments. I believe that the tank is a weapon with which those in authority have learned their lesson. They have resisted the temptation of building a vast army of heavy vehicles which would look excellent on a birthday parade, but might prove exceedingly vulnerable in future hostilities. The vital importance of speed is, at last, appreciated. They have been fortunate in having behind them the best engineers in the world and the benefit of Britain's great motor industry. This may well prove as important to the nation in another war as Germany's chemical industry proved to her in 1916.

Tanks are only a small part of mechanized forces. Tractors are now the accepted method of taking big guns into position, troops do not have to face long marches with a heavy pack, if the men themselves cannot be carried, their equipment will be taken for them on fast trucks. The use of trucks to carry supplies has been of great strategical value since, not only is speed gained, but the weight of petrol required to carry a given amount of food or ammunition is much less than that of the fodder required by horses to transport the same weight. Very largely the story of mechanization is the story of the adaption of commercial motoring to military purposes. The army has a vast number of motor vehicles of the same type as you see on the roads, from the "baby" car for carrying officers rapidly from one position to another and the motor-cycle for messengers, to the six-wheeled lorry which is a utility

vehicle capable of crossing rough ground carrying anything from soldiers to ammunition, as well as towing medium or light guns. In addition there is a store of mechanical equipment developed from road-making. There are mechanical trench diggers, power picks or shovels, mobile repair shops and every conceivable appurtenance which warfare now demands.

It is interesting to note how each of the major industries has produced a major weapon; the chemical industry gave us high explosives and poison gas, the railways showed how to move conscript armies of millions to mobilization within a few days and the motor industry has given the army a further mobility it has never known since gunpowder first threatened man-at-arms or his mounted counterpart.

CHAPTER XII

CAMOUFLAGE

CAMOUFLAGE, the science of concealment is far older than Man. Long before the first men made their appearance on the earth and had founded the art of war, animals, birds, insects, all were pastmasters of the art of camouflage; natural selection or the survival of the fittest resulting in the evolution of types best able to elude their enemies. The camouflage of Nature varies from simple colouration, the white coat of the rabbit in arctic regions, to imitation by shape and colour like the stick insect which appears to be part of the plant on which it is living. In between we have camouflage by light and shade effects which blend with the animal's normal surroundings. These are found chiefly in the larger animals. Well-known examples are the tiger's stripes which merge with the light and shade of the long grass in which it is generally found, rendering it invisible when it is still. The patchy colouring of the giraffe gives exactly the effect of strong sunlight shining through leaves and makes the animal inconspicuous in the tropical forests which are its home. Most animals will be found to be coloured more darkly on the back than on the lower sides and belly. This is no accident,

there are no accidents in Nature, but is one of the great principles of camouflage which is to be explained.

The use of camouflage in warfare is also extremely old, although until the development of long-range weapons it was primitive and only occasionally of real use. As long as one had to be within a few feet of the enemy before he could be killed, there was little object in concealment, although simple camouflage devices were used to allow of surprise attacks. We can assume that the Lincoln green worn by archers, and notably Robin Hood, in Sherwood Forest was chosen because it blended with the surrounding trees. Actually, if Robin Hood were alive to-day, the science of camouflage would provide him with a suit not of pure green, but perhaps of dirty green blotched with yellows and dull greys. This would give more effectual concealment than green, even through the green "matched" the leaves of the forest. One of the most elaborate of historical camouflage attempts is described in *Macbeth*. The advance of an army covered with branches allowed Macbeth to be surprised. Branches are still extensively used in camouflage although any modern commander would be doubtful of the possibility of approaching his enemy unseen by the mere artifice of holding leaves in front of his body.

The introduction of camouflage into modern warfare really began with the uniforms of soldiers. For thousands of years European soldiers were dressed in gay colours. War was a spectacle, so that smart and gaily-coloured uniforms were good for recruiting. "Redcoat" was the name of the British soldier. The fact that red was one of the most conspicuous colours and made

the wearer a vivid target did not worry military experts. Battles were fought according to rules. Soldiers lined up a few paces from each other and at the word of command fired. The use of uniforms intended to conceal the wearer would have been against the rules of the game and might even have been considered unsporting. You will recall the famous battle at which the English commander insisted on giving the enemy "the honour" of firing the first volley. Unfortunately, when European armies began to meet savages, the latter did not know, or more sensibly, would not observe the rules of the game. They had the barbarous idea that the object of war was to kill as many of your enemies as possible without being hit yourself and they showed themselves masters of concealment in forest or jungle. Their brown skin and scanty clothing made it simple for them to blend with trees and bushes from which they "sniped" the red-coated soldiers who presented a perfect target.

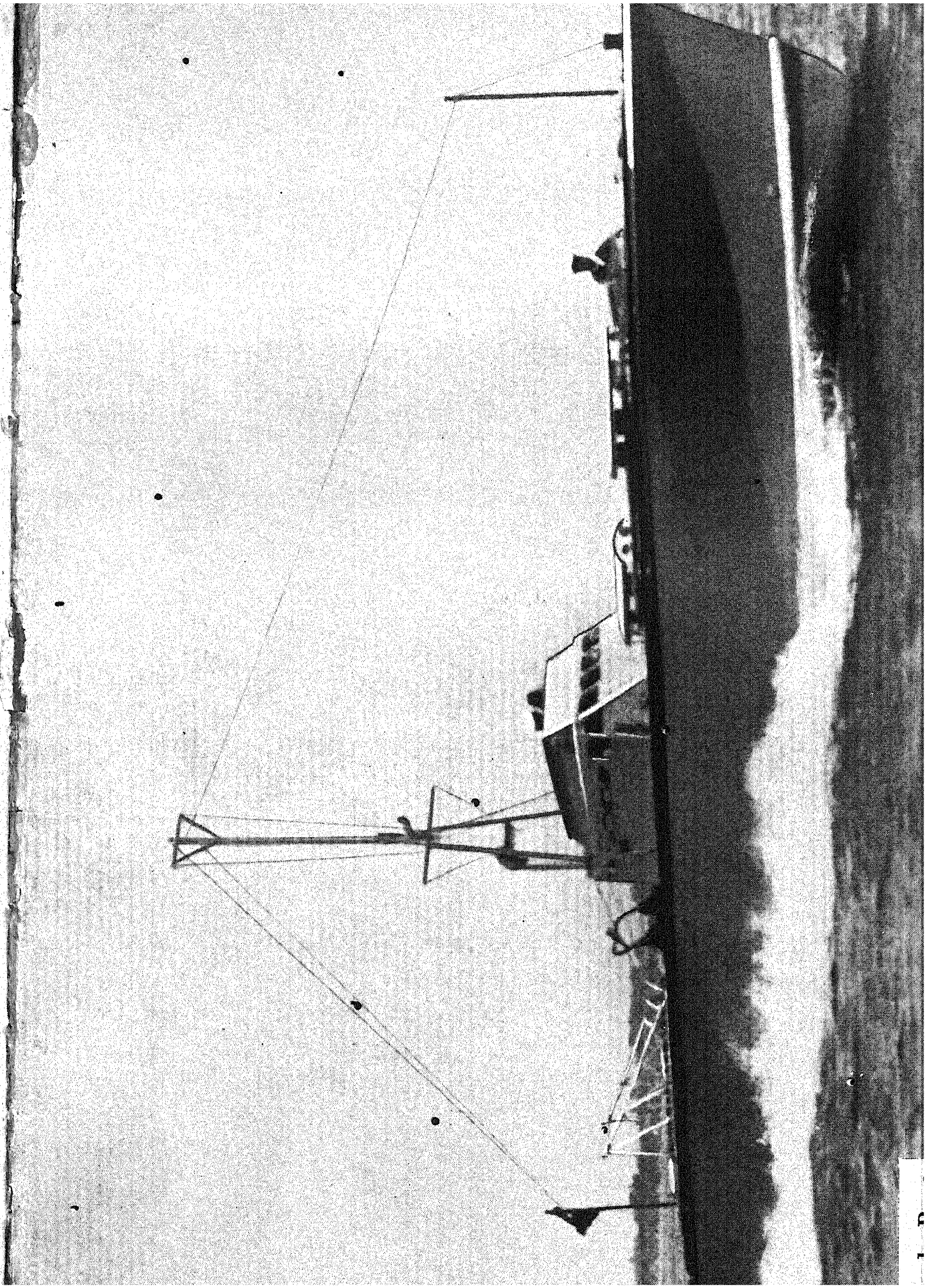
British generals fumed, but it took many years for them to learn from savages. The tremendous losses that occurred in the close, red-coated ranks in America did not teach them a lesson, although a few companies of riflemen with camouflaged uniforms were introduced. At the Battle of Waterloo all three armies would not have been out of place in a ballroom, while officers were particularly conspicuous by the brilliance of their uniforms. Even in the Crimea, the standard uniform was still red and it took the Boer War to teach the British experts a lesson that should have been obvious a century before. The Boers, many of them wearing ordinary clothing, were almost invisible compared with

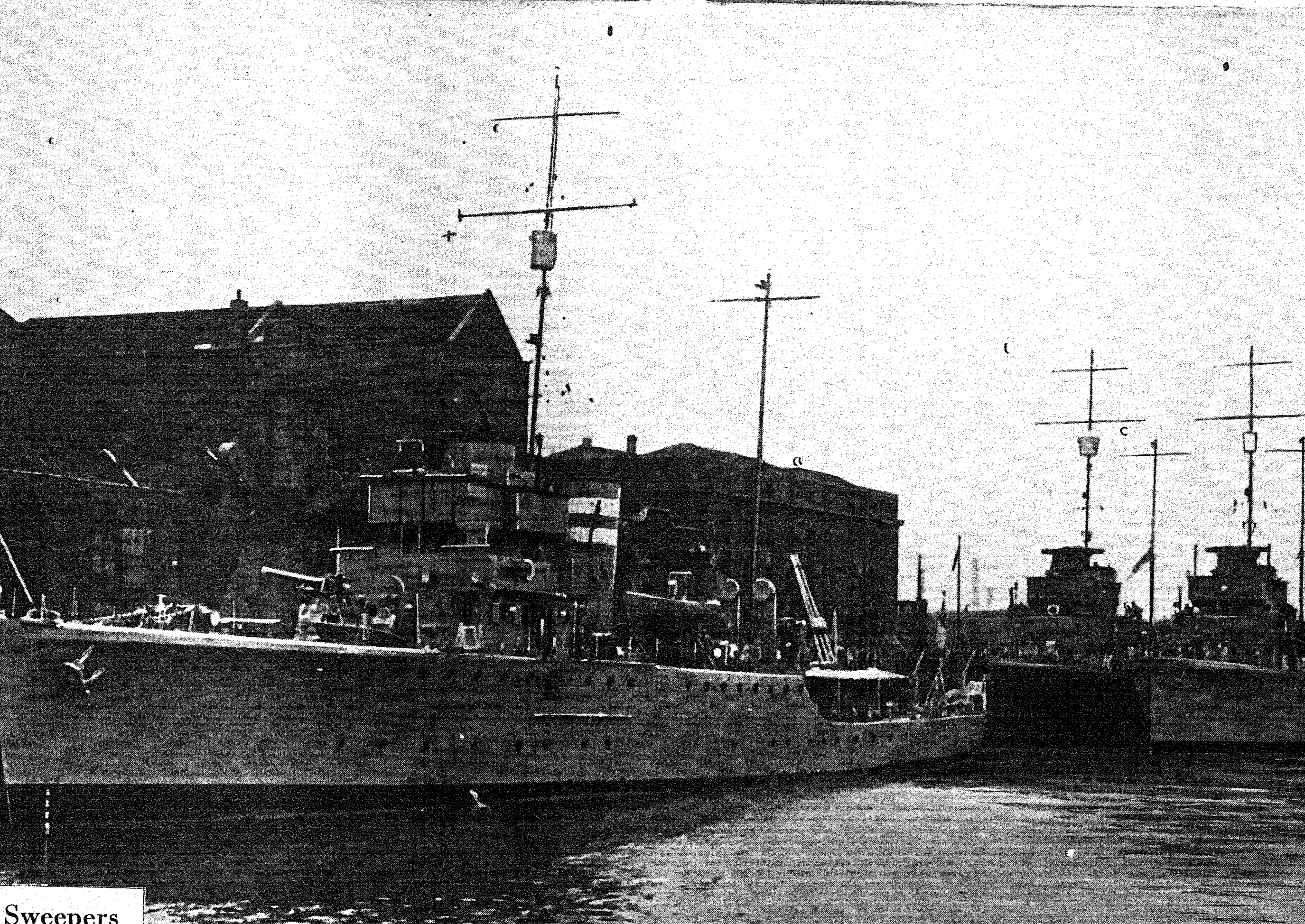
the brightly-clad British, and heavy losses forced khaki uniforms on the army. It has been the standard uniform ever since, and all the other armies of the world use some colour which blends with natural surroundings, field-grey or grey-green.

The camouflage of uniforms was greatly developed during the Great War. Bright buttons were covered over, the glint from one of them might reveal the whereabouts of a whole platoon of men. Steel helmets were painted over instead of being prized for their brightness as in olden times. In active service, at least, "spit and polish" was shown to be inviting death. The uniforms of officers which had made them conspicuous marks for centuries were made as like those of the men as possible. In addition to the changes in standard uniforms, special uniforms were developed. For fighting in snow, white robes were used, the wearer thus presenting a very difficult target.

Camouflage falls into several distinct branches. The first and simplest is the concealment of a person or thing from direct observation, by imitation. The easiest form of concealment is a blending with the background, so that the target does not stand out. This is the object of the khaki uniform. Few natural objects are coloured khaki, but this colour is not conspicuous against most natural backgrounds.

More elaborate camouflage is secured by the imitation of natural objects. An observation post, for instance, may be made of a framework that resembles the stump of a tree and inside this a soldier may sit with field-glasses and map, noting the movements of the enemy so that these may be telephoned back to his





Sweepers

battery. Attention to detail is necessary in such cases if the camouflage is to be a protection and not a death trap. To-day, enemy positions are subject not to more or less casual inspection with the naked eye, but to searching scrutiny with field-glasses. The "peep hole" of the observer in a dummy tree would be revealed immediately, and therefore is covered with gauze coloured to match the rest of the surface. The gauze does not prevent anyone inside looking out but cannot be detected from even a short distance. Then again, care has to be taken that under no condition does light shine through any opening from behind, or the peep-hole will immediately become obvious.

Not all observation to-day, however, is direct. The aeroplane has revolutionized observation and the chief concern is not to be seen from the air. This is made all the more difficult, because photography is a powerful weapon of aerial observation. Two photographs taken on different days of the same spot can be minutely compared and any small differences immediately noticed.

To understand the science of much of the apparently meaningless camouflage applied to guns and factory roofs, it is necessary to appreciate that what the camera sees from the air is deputed by varying degrees of light and shade. Shadows are all-important, for even though, for instance, a battery of guns may be covered with a screen of branches, to make them look like the surrounding trees or a copse in a field, they will cast a shadow which the camera will immediately detect, particularly in photographs taken in the early morning or late evening when the sun is low. To overcome this,

camouflage throws the whole structure into shadow and this is accomplished as follows.

If you look down at a white cube from above you see first of all a conspicuous square of white and also a shadow. To the experienced observer, there is no mistaking the size and shape of the object. But if you paint the top of the cube grey or nearly black, it will blend with the shadow so that what is seen gives a completely misleading idea of the shape of the object. If the whole shape is arranged to blend with the surroundings, it may be passed over as a part of the landscape.

To camouflage a gun in a field, a net is erected over it. In the centre this net is either covered with grass, branches of trees, or cloth painted to resemble them; but towards the edges, the net is "shaded away", gradually becoming quite open. The open net conceals what is underneath, in the same way that net curtains over a window conceal what is in a room, but do not cast a shadow. The result is that an airman, if his eye is attracted to the spot at all, sees an irregular blotch which might be a piece of cultivated ground or some other quite ordinary feature of the landscape. One of the fundamentals of camouflage against aerial observation is that everything should be irregular and rounded, geometrical shapes immediately attract attention. This is in contrast with another branch of camouflage with which we must deal, the dazzle-painting of ships, carried out with quite a different object.

Several special problems arise out of the concealment of guns. One of them is the need for hiding the

tracks leading to the guns. The battery itself may be well hidden, but the tracks along which the crew and the ammunition reach it will stand out. It is impossible to conceal these, the principle of deception is, therefore, employed. The position of the guns may be chosen so that already established tracks are used. A photograph will show these tracks, but since they are not new, they will not excite the interest of the enemy. The tracks may be artificially extended so as to appear as if they were leading somewhere else, if they are continued right through the gun positions to a road, for instance, the enemy will jump to the obvious conclusion that they were used simply for getting to the road. Then guns produce characteristic marks called "blast marks", which are immediately detected by aerial photography. These can be concealed by direct covering like the guns themselves or by blending them with tracks apparently leading somewhere else.

In concealing buildings from aerial observation more difficult problems arise and one can say that it is impossible to conceal a large building from close observation. Generally, however, observing planes or bombers have to fly at a considerable height, and airmen can be deceived by some forms of camouflage. This may be accomplished either by making the building blend with the surrounding landscape or by painting it so that, instead of a large factory, for example, it appears as a row of small houses which would not be considered a mark for a bomber. The latter scheme is accomplished by painting in red splashes and if, on close inspection, you find it incredible that any airman should be deceived, you must remember that

he is observing vertically from a considerable height, or that it is natural for the human eye to jump to conclusions. The concealment of a factory by painting it to resemble small houses would only be effective where the factory is, as so many are, in the middle of a small housing estate. The red splashes continue the line of houses and seem quite natural.

The more general method of camouflage, however, is to make use of light and shade, and by painting the roof of the factory to make it appear from the air as a confusing medley of fields, trees, or isolated houses, in keeping with the surrounding landscape. The camouflage of buildings to protect them against aerial attack which is being so extensively carried out in Britain nowadays, can, fortunately, be carried out at comparative leisure and need not be rushed through like the camouflage of guns in the field. The scientific method is to photograph the buildings to be concealed from the air at different times of day and from different positions. These photographs are studied, possibly a model is made, and a plan formulated. Because the north side of any building is always the darkest, this will have to be painted lighter. The whole object of the painting will be to produce a confusing mass of apparent shadows.

Camouflage is usually carried out in final terms of black and white. From the air, colours do not count nearly so much as shades and, of course, in the normal camera, everything is rendered in monochrome. The development of colour photography may mean the adaptation of different camouflage, but the greater the height from which observation is made, the less does

colour count in comparison with degrees of light and shade.

The camouflage of large towns against attack is impracticable, but we may see the development of spectacular plans designed to deceive enemy craft, particularly at night, during actual warfare. To carry out these plans in peace-time might be to negative their value. Italy is already said to have built several dummy "villages" designed to lead hostile bombers astray. To deceive the enemy it is not necessary that an object shall be like the real thing, it is only necessary that it shall appear like the real thing. What does a town look like from the air at night? Just a string of lights. Put up a few hundred lights strung on poles in the empty countryside, arranging them in straight lines, and a man looking down from an aeroplane will think they are a town. He will look at his map, identify, as he thinks, the place, and either waste his bombs on the empty country or be completely led astray in his bearings so that he is unable to find the real objective. In the Great War, such aerial landmarks as lakes were drained when they were in or near big towns. In the next war we may find that artificial lakes are created in the country in order to lead the enemy astray. A large area daubed in bright paint, with a few lights nearby might lead the enemy bomber to think he has found the Serpentine when, in fact, he was flying over some lonely part of the Sussex downs.

Aeroplanes are now also camouflaged, being painted with patterns that give the effects of light and shade. Bombers are painted black to make it difficult to detect them in the night sky; the latest practice being to

camouflage them from searchlights below, and from other aeroplanes, above.

The science of camouflage is concerned not only with concealment but in misleading the enemy into thinking he has found something important when, in fact, he has not. The examples that have been given will explain this branch of camouflage. In the field, the enemy may be led away from important targets by having his attention drawn to dummy guns or ammunition dumps. Erecting these dummy objects so that they deceive is a science of its own. An interesting use of dummies was the making of dummy heads to track snipers. The head would be raised above a trench parapet and the course of the bullet is received traced so that the exact direction from which the sniper was firing could be discovered.

Camouflage at sea presents problems completely different from those encountered on land. Normal camouflage would demand the disguising of a ship so that it became invisible or blended into the seascape so that it could be detected only with great difficulty. For centuries ships had been painted black and white—the colour of British warships was formerly black hull with a white upper structure. Battleship-grey, intended to make the ship match the water, is believed to have originated in the United States towards the end of the last century. It is said that after the Spanish-American War two squadrons, one of which was painted grey, and the other black-and-white, met at the victory review and the contrast was so obvious that even the lay spectators decided there could in future be only one colour scheme for warships.

But grey is only a partial protection, for the colour of water varies considerably from place to place from grey-green to bright blue. Moreover, a ship appears to a gunnery or torpedo expert in silhouette so that colour and other considerations apart, its smoke gives it no hope of escaping unnoticed on the open seas. It was not until the idea of invisibility, such as can be achieved on land, was abandoned, that any real progress was made with camouflage at sea.

The stimulation to research was the German submarine campaign on mercantile shipping, and artists turned to an older idea, that of "dazzle painting", based on the idea not of rendering an object invisible, but of making its direction hard to determine. The first experiment in dazzle-painting seems to have been the painting of the forts at Spithead in black and white squares, making it difficult to detect the exact position of batteries. In adapting this idea to ships, the camouflage experts had in mind that, if a ship cannot be concealed, the next best thing is to deceive a submarine commander as to size, speed and direction, for on these facts he bases his torpedo attack. The silhouette of the ship enables him to identify it, or at least place it in a certain class. Knowledge of the performance of the type with its direction or speed as he sees them gives him the moment to launch his torpedo and its direction.

Various systems of dazzle-painting, all with the same main object of making the exact course of the ship difficult to discover, were evolved. One called for bands of violet, grey and olive which shaded away from the water. Another depended upon brilliant colours to emphasize certain portions of the ship. But experi-

ment showed that colour was of little importance, particularly after enemy submarine commanders were supplied with periscopes fitted with colour screens that enabled them to view targets in black and white.

The ultimate plan adopted called for black and white as the most important colour, grey, green and blue being used for patches. A typical scheme was that used on the *Leviathan*, the bows of which were painted white, the colours darkening towards the stern. This not only made the great ship appear smaller, but appear as if it were travelling on a course several degrees away from its actual course. A different scheme is adopted for every ship, according to the particular problems involved. False funnels and superstructure have also been used to disguise a vessel's silhouette in every possible manner.

The puzzling effect of dazzle-painting can be appreciated in some degree from a picture, but it must be remembered that a picture can be carefully studied, whereas a submarine gets only short glimpses of the target through a periscope from a very low view-point. The deceptiveness was proved on a number of occasions when torpedoes from a submarine of which the presence was not even suspected, passed some distance from ships. How many others were fired and never seen can only be a matter for estimates.

The geometrical figures, patches and lines of dazzle-painting seem so grotesque in harbour that it is not surprising British sailors were difficult to persuade to the idea. The lines seem to emphasize the target rather than conceal it and this in fact is what they are intended to do, but they emphasize, from the enemy's point of

view, the wrong parts. They are not designed to prevent an attack, but to make the attack abortive on the grounds that a miss is as good as a mile. Eventually, every British merchant ship and some 400 warships were dazzle-painted; it is practically certain that in the event of hostilities, all ships would be dazzle-painted from the very beginning. If dazzle-painting depends upon a mere knowledge of perspective it should be called an art, but a real understanding of the principles of optics on which illusions are based is hardly less necessary, so we may reasonably refer to camouflage as another technical adaptation of nature from one class of warfare to another which is equally ruthless.

CHAPTER XIII

IN THE AIR

THE ENTRY of war into a third element, the air, had a far-reaching effect. In the earliest days the sea presented a barrier which, while it did not make islands immune from invasion if they were within easy striking distance of enemies, at least provided obstacles and made it possible to concentrate defence in certain limited directions. Because Britain has no land frontiers, she has no history of invasion or frontier war such as nearly every Continental country knows too well. The crumbling remains of the Roman Wall in the north are the nearest approach to a "Maginot line" that she has ever known. For centuries her "frontiers" were the Channel and the North Sea.

The invention of the aeroplane has completely changed these conditions although some thirty years have passed without their full significance being realized. The threat of actual invasion from the air is small, and will probably remain so for many years. To carry by air a force large enough to conquer a country involves great difficulties. But wars are not won only by invasion. Indeed, the main object of invasion is to reduce the people to such a state that submission

must follow. Submission of this kind might be obtained by the use of aerial weapons without a single soldier setting foot in the land.

The destruction of industrial centres and means of communication, or the disorganization of the life of a country to a stage where resistance is impossible, could be achieved by bombing from aeroplanes travelling from bases 500 miles or more distant. It is astonishing that this was not realized on the day when the Wright brothers made their first flight, much more astonishing that it was not grasped when Bleriot flew the Channel, even more absurd that it was not fully understood after the Zeppelin and aeroplane raids of the Great War. To-day, quite a large number of people look upon air defence as a matter of personal safety and do not fully realize that to render air attack ineffective has the same importance to-day as had the mastery of the seas during the Napleonic Wars.

Historically, air warfare goes back to the days of ballooning, but it was of little importance until the invention of the aeroplane. The most that could be expected of balloons and man-carrying kites was that they could provide a higher viewpoint of "spotting" for guns. Balloons were attached to the army, for experimental purposes, sixty years ago and during the Boer War they played quite an important part as auxiliaries of the artillery. One writer says that they annoyed the Boers not only because they enabled artillery fire to be directed more accurately but because they showed the scientific superiority of the British army. These balloons were, of course, all captive, of the type now used for maintaining the barrage round London, with

the difference that they carried an observer, and that not until some time later was the "sausage shape" introduced to give stability so that the balloon would face the wind without turning. Similar balloons were used throughout the last war for observation purposes, although they were no longer safe because of the attacks of enemy planes equipped with incendiary bullets.

A scheme was put up to Napoleon for the use of free balloons to cross the Channel and bombard London, although how the balloons were to be guided over London is not at all clear. In any case, this air raid on London never materialized and England was to remain free of the shadow of the air menace for more than a century. The fact that a balloon was entirely at the mercy of the wind, although a skilful aviator could exercise a certain amount of control, ruled it out as an offensive weapon. The only use of the free balloon was to carry messages from a besieged city, and this was actually done during the siege of Paris.

The invention of the internal combustion engine which had such far-reaching results in so many directions, made possible the powered airship and with the building of the first successful Zeppelins, the possibility of visiting enemy territory or dropping bombs became a reality. The first Zeppelins were actually used for passenger-carrying and although, during the war, many gained the impression that these craft had never been intended for anything but the bombing of civilians, they were used for co-operation with warships with great success.

The Great War raids on London showed that airships did not constitute a major menace to "open"

towns. Raids became progressively less successful until they were given up altogether. The amount of damage done was very small in proportion to the expenditure of money, and by 1918 defence measures were fairly effective. Nevertheless, the constant threat had a certain effect on the morale of the population. Air raid warnings, anxious nights, as well as the disorganization of industry due to "black-outs" could all be placed to the credit side of the Zeppelins which locked up a number of men and guns on the home lands. It is generally agreed to-day that in spite of the tremendous load of bombs that could be carried by large airships, they are not likely to be of great service in future hostilities. Slow speed and their inflammability when hydrogen is used makes them fairly easy victims to the modern aeroplane. The advantage of height which Zeppelins enjoyed during the Great War no longer exists and the mounting of cannon firing explosive shell now greatly adds to the destructive power of the fighter aeroplane. The United States has been experimenting along new lines by using large airships to carry aeroplanes, releasing them when near the objective. This has been done for purposes of naval co-operation, but whether the advantages over the aircraft carrier are such as to justify the considerable expense, is very doubtful. Small non-rigid airships, or "Blimps" as they are called, may continue to do patrol work, especially in search for submarines. They have advantages of economy over aeroplanes, but they are limited to areas where they are not likely to be attacked.

We come, therefore, to the aeroplane which entered the Great War virtually unarmed, very uncertain of its

place in warfare, and emerged from it a fully fledged arm of the fighting forces playing a major part in all engagements on land and sea as well as acting independently in the raiding of enemy territory.

Great Britain had less than 200 aeroplanes at the beginning of the last War, none of which would have been given a certificate of airworthiness by the standards of to-day. Their armament consisted of rifles, revolvers and hand-grenades with various "home-made" devices with which it was hoped to entangle the enemy aeroplanes' propellers. As fighting craft they were not very dangerous, but it must be remembered that they were only meeting aeroplanes similarly armed. Fighting was, indeed, incidental, the chief function of aircraft being the observation of gun fire and enemy troop movements. There were no bomb racks, no bomb sights and such bombs as existed were often as dangerous to the aeroplane carrying them as to the targets below.

The difficulties of arming these early aeroplanes were several. First of all was the question of weight. Every pound counted and there was a very definite limit to the weight that could be allowed even for a machine-gun. Armaments had to await aeroplanes with greater lifting power. Then there was the difficulty that firing ahead, the most useful direction, was prevented by the propeller and the further trouble that control of the aeroplane occupied the pilot's whole attention so that an observer or gunner was necessary.

These failures were overcome in due course. The military aeroplane, until 1916, was usually a "pusher", that is to say, the air-crew was behind the fuselage,

leaving the pilot and observer a clear view in front. This was less efficient than the tractor, but there seemed no alternative. In some planes, the difficulty of the air-screw being in the line of fire was overcome by mounting the guns high up. In recent years there has been a return to this idea in principle, with guns mounted on the wings and firing clear of the propeller. The solution of the difficulty of using tractor airscrews with forward mounted guns taxed the ingenuity of inventors all over the world.

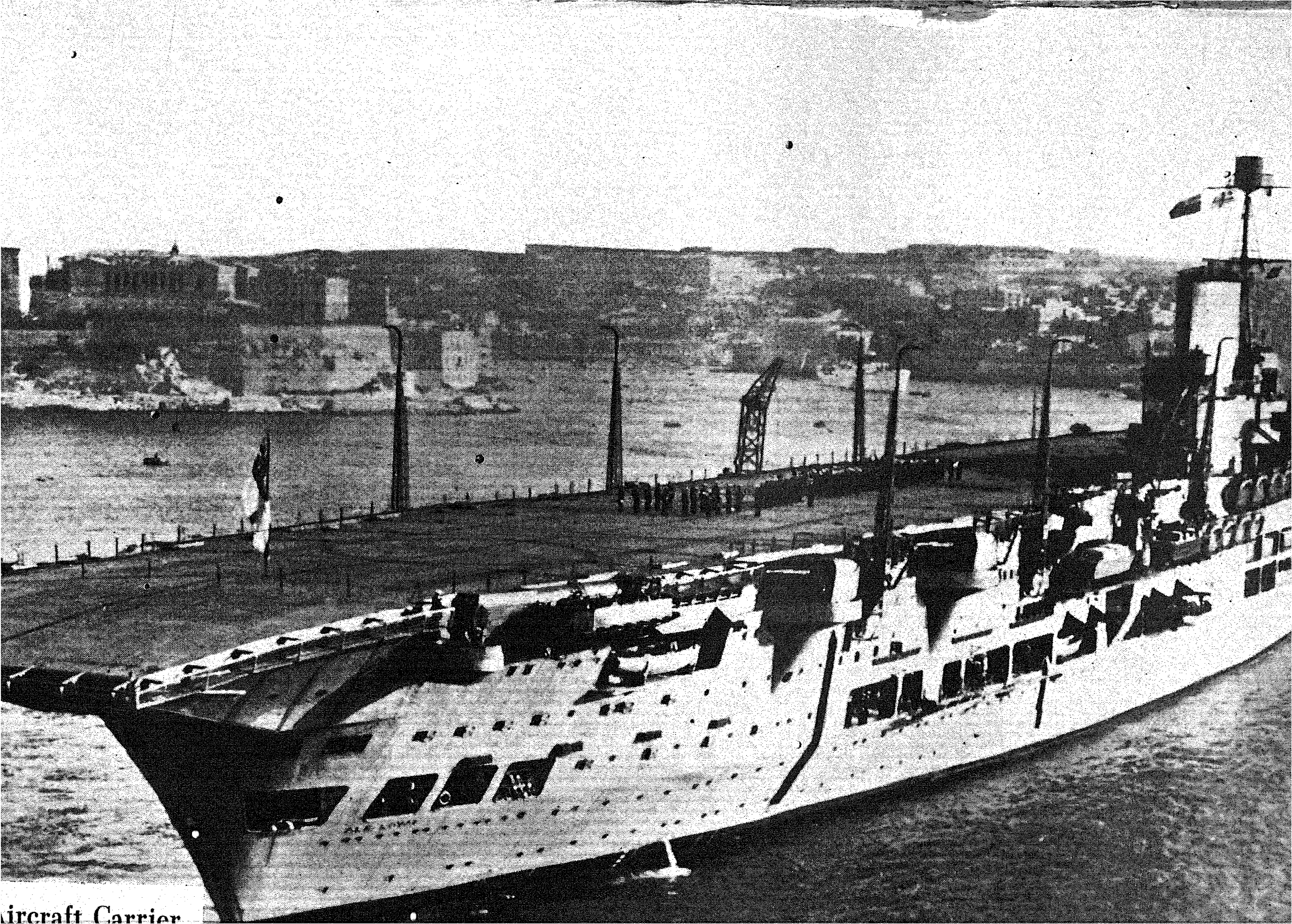
The first idea for firing through the propeller consisted simply of firing a machine-gun and letting a certain number of the bullets strike the propeller. Special steel blades were fitted to take the impact of the bullets which do not seem to have done very much harm. But obviously the real solution was to have some method of interrupting the stream of bullets at the moment the blade passed in front of the line of fire; in other words, synchronizing the propeller with the gun. This was first accomplished by the Germans and in 1916 by the British with a superior device. This method, in principle, is still used to-day. The invention, one of the most brilliant of the War, revolutionized air fighting. It was made by M. Georges Constantinesco and, non-technically, utilized the engine to fire the machine-gun by the pulsation of oil in pipes. The result was that the observer could be dispensed with and the weight saved utilized to increase the speed of fighting planes. Moreover, the pilot could crouch down behind his engine, obtaining a certain amount of protection, and presenting a smaller target.

The synchronized gun was fired by levers fitted to

the "joy-stick" so that the pilot could bring his gun into action without removing his hands from the controls, a very necessary thing with air fighting developing at high speeds. The gun firing through the airscrew was necessarily "fixed", that is it could not be manœuvred to bear on the enemy. In bombers and two-seaters, a gun on a flexible mounting which could be turned in all directions, continued to be used.

The story of development of military aviation for the rest of the Great War is chiefly that of improvements of existing inventions, the increase in speed and climb of fighters or of load carried by bombers. An increasing number of duties were found for aircraft, not the least important of which was aerial photography. Towards the end of the Great War over 100,000 pictures a month were being taken from the air. It was found that aeroplanes were suitable not only for attacking raiding planes and bombing enemy positions behind the lines, but for bombing or machine-gunning front line trenches. The low-flying attack was developed and because of the difficulty of firing at a fast-moving target at short range, the planes were safer in some ways when flying a hundred feet above the ground than when flying at several thousand feet.

The modern military aeroplane is a development of the various types evolved in the Great War. It is often said that military aeroplanes are simply commercial aeroplanes adaptated for special purposes. This is quite true. Completely different qualities are sought in the military aeroplane, which must be specially designed. The only possible adaptation would be that of air liners into bombers, but this is not nearly so simple as it



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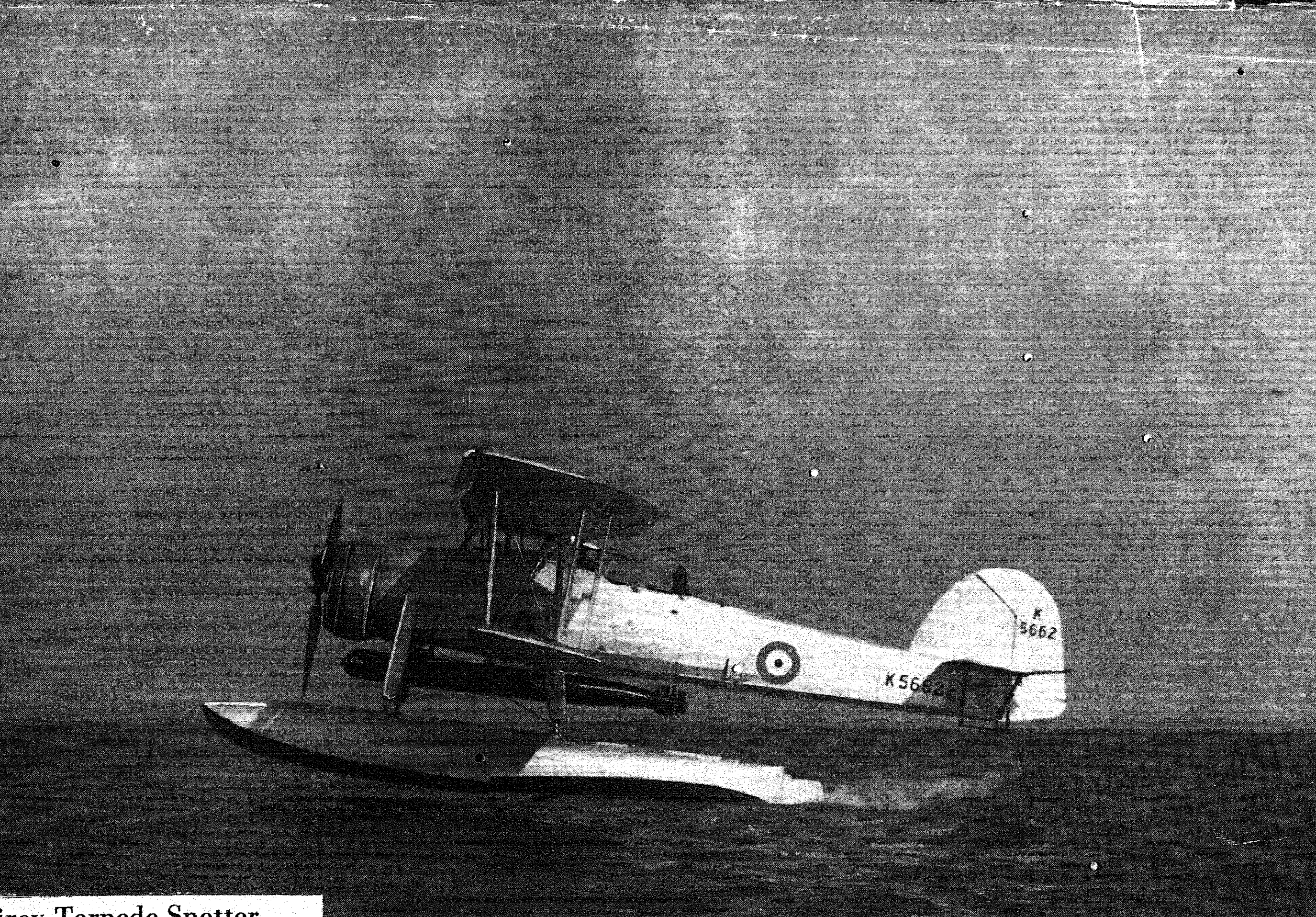


irey Torpedo Spotter

sounds, and certainly no easier than the conversion of Atlantic passenger liners into warships. At best they can only become armed merchantmen. The design of military aircraft is highly specialized. The fighter requires a fast climb and great speed for short distances, useless to the commercial craft. Economy, so important in civil aviation, does not count with military aviation. These are only some of the fundamental differences. What is more than possible is that experience gained in the rapid mass-production of military aeroplanes for replacement may be of great value in enabling commercial aircraft to be produced cheaply and efficiently. Always assuming that commercial aircraft are not impeded in their development during the race for arms.

It would be impossible to deal individually with the many different types of fighting and bombing aeroplanes produced to-day. We can only consider some general features, more particularly in the light of the brief history of this subject. The single-seater fighter is not at least twice as fast as the best that appeared during the Great War. Some types are three times as fast, with one thousand or even two thousand horse-power, and the question will shortly arise whether we are not reaching the point where certain temporary limits, not of human endurance, but of human control, are reached. Experience in Spain suggests that some of the fighters are so fast that it is very difficult to aim the guns. A target may bear only for a fraction of a second and while it is true that the number of bullets delivered may now amount to several thousand a minute, the difficulty experienced by a pilot in simultaneously controlling a plane moving at, perhaps, over 500 feet

a second, while bringing his guns to bear on another target moving at a similar speed, is considerable.

The guns used may be divided into two types, the fixed and the flexible. The fixed gun fires along the axis of the aeroplane, that is dead ahead. The pilot, therefore, "aims" his aeroplane at his target. In the latest fighters more than one gun may be mounted and some aeroplanes have two on each wing, the four converging slightly so that a "cone" of bullets is formed about two hundred yards ahead. No aeroplane, however fast it is travelling, is likely to survive passage through this cone. This mounting of the guns has the disadvantage that once in the air the pilot cannot correct any faults in the guns, but the advantages of clearing the cockpit of gear and giving a very greatly increased rate of fire probably outweighs the disadvantages at the speeds at which modern air battles are fought.

For both the gun firing through the propeller and the gun mounted on the wings, the pilot has a sight, or rather sights, to enable him to tell when his target bears. These sights, of various types, are very ingenious. The old open sights which showed the actual target on cross wires are not altogether satisfactory when an aeroplane may travel 50 yards in the interval that elapses between the trigger being pressed and the bullet arriving at the target. In one sight, the position of the pilot's eye is not of importance so long as he can see his target through a tube. A series of lenses are so arranged that the necessity for keeping the eye "glued" to the sight is avoided. New "visible" sights are being developed, making use of mirrors and electrical devices which will simplify the difficulty of firing a "burst" at

a rapidly moving target from a plane which is moving, perhaps, equally rapidly, in another direction. Range is not of importance, the sights being fixed for about 200 yards. For practical purposes the trajectory of the bullet fired straight ahead for this distance, is flat, but there are other serious problems of angle, introduced by both speed and windage.

The fixed gun can only be fired straight ahead. This is satisfactory for the fastest fighter which can rely upon its superior speed to give it position. Bombers, reconnaissance planes and general purpose aircraft may have to tackle fighters approaching from the rear or from above or below so that flexible mountings for guns are essential. Great engineering ingenuity has been shown in devising flexible mountings not affected by the wind and yet able to be moved without the use of much muscular force; a number of guns can be distantly controlled, hydraulically, almost by the touch of a finger. The increasing speed of aeroplanes has necessitated some protection for the gunner from the wind stream and, to-day, he is usually placed in a turret or behind a screen of transparent material. Aeroplanes are designed to give as wide a circle of fire as possible. Another problem which has been overcome is that of the "freezing" of the oil used in the guns at the extremely low temperatures experienced at great heights. Artificial warmth is now provided where necessary. Sights for flexible guns are ingeniously devised to allow for deflection due to the relative movements of the gun and the target.

A few bullets, unless they strike a small vital area, are insufficient to destroy a modern aeroplane and

for this reason the mounting of "cannon" has been adopted. The cannon fire small shells about $1\frac{1}{2}$ lbs. in weight at a speed up to 100 a minute, a direct hit with one being sufficient as a rule to destroy even a large bomber. We may see here the development of the same contest as has taken place at sea; aeroplanes being armoured and cannons becoming more powerful. Armour-piercing shells are already available. The chief difficulty in mounting cannon is the recoil, a "pressure" of some 1,500 lbs. having to be taken up in the mounting.

The other armament of the aeroplane is the bomb. The first bombs were exceedingly primitive and during the early days of the last War steel darts were released, owing their power entirely to the force of gravity. The construction of bombs has already been described; but particular interest attaches to the usual methods of release and aiming. The bombs are generally held horizontally on the aeroplane in clips which are opened either mechanically or electrically. The latest bombers have elaborate releasing devices which enable one or more bombs of the whole load to be dropped as required.

The problems involved in dropping a bomb are many and although progress has been made, it would be wrong to suggest that bombing has yet attained anything like the accuracy of artillery fire. The factors involved are first of all the speed of the bomber; the speed of the target, if it is a lorry or ship, the speed of the wind, and the height at which the bomb is released. The bomb falls forward at, roughly, the same speed as the aeroplane from which it is released so that it must be dropped some time before the target is

reached, the exact distance depending upon the height of the aeroplane and other factors. With modern high-speed bombers at a considerable height, this may amount to five or six miles, and means that the observer must have a good view of his target. For this reason he is given a special observation position in the front of the machine where he has an unobstructed view. This, incidentally, is a point to bear in mind when considering the possible damage that might be done by raiding aircraft. The number of days on which a clear view of a target six miles away can be obtained from 20,000 feet up is limited.

To assist him the bomber has an elaborate sight which makes the necessary allowances for the various details mentioned. He must have the aeroplane flying perfectly level and steady at the moment of release or all his calculations may be wasted. Levelling out takes about a minute during which time a modern bomber may travel five miles, so that the problem of bombing small targets from a great height is not so simple as might be imagined. It is this fact, perhaps, that has led to the belief that battleships are not so vulnerable to bombing as was at first supposed. To overcome some of these difficulties as well as to present a more difficult target to anti-aircraft guns, the manœuvre of "dive bombing" has been developed. This consists of putting the bomber into a vertical dive, literally aiming it at its target, the bombs being released at the end of the dive just before the machine pulls out. Bombs released in this way will fall almost in a straight line; the manœuvre has the further advantage that the bomber can approach at a great height and then

drop on its target in less than one minute. This manœuvre is suitable rather for the attack of small and limited targets, such as battleships, than for towns. There are of course, many other methods of mass or repeat action bombing which are well adapted for use against moving targets.

Military aircraft to-day, both fighters and bombers, are exceedingly formidable. Whether the fighter has kept pace with the bomber is doubtful, for the speeds of the two types have tended to approach more closely. Moreover, the bomber to-day carries considerable armament and is no longer "easy meat" for any fighter that can get on its tail. It is certain that no country anticipates being able, by the use of interceptor planes, to bring down every bomber. At the same time, the great improvement in anti-aircraft fire and searchlight technique has made the attacker more vulnerable. An estimation of the exact chances of any country being able to subdue another by a series of raids would require a treatise to itself, and it would still remain guesswork. One of the striking facts of recent wars has certainly been that a vast amount of high explosive can be dropped without doing a proportionate amount of damage and it is possible that those responsible for the direction of air forces will concentrate on real military targets rather than "open" towns, not out of humanity but for effect.

While improvement in the speed and armament of bombers has been considerable in recent years, methods of "offensive-defence" have hardly kept pace. They may "catch up" during the next year or two. Already there has been a great development of the quick-firing

cannon or multiple "pom-pom" which can deliver a barrage of small shells at low-flying aircraft. The balloon barrage system offers a further obstacle to night raiders, not so much because they are likely to fly into cables hanging down from the balloons as because knowledge of them will cause a certain amount of uncertainty and tend to keep raiders up to a height where accurate aiming is not easy. Undoubtedly in the near future methods of sowing "mine fields" in the air will be developed. These would consist of small balloons carrying explosive charges, fired by contact. There are other developments of controlled rockets which may prove effective in the carrying of grapplers, fire, gas or dust clouds.

We already have air fleets manœuvring in lines and it is probable that air combat will develop along the lines of naval warfare. The mine fields will call for mine-sweepers, the barrage for planes which attempt to destroy the balloons and make way for the big bombers. The effect may well be to neutralize the position, we must remember that Trafalgar was a bloodier battle than Jutland. The war in the air will develop, perhaps, to the stage where armies will not engage until one side or the other has asserted its aerial supremacy. Half the ordinary man's terror of the air-war is due to its novelty. This will disappear in time and, if we continue to fight, we shall take the threat of bombing in much the same way as people on the Continent have accepted the fear of invasion by armies which have only to cross a frontier a few miles away, to burn their homes or indulge in a general massacre before rescue could be at hand.

CHAPTER XIV

PARACHUTES

THE parachute is older than the aeroplane, older than any form of flying. Early experimenters realized that a large surface could be utilized to make use of the air resistance to provide a moderately slow drop to earth from a height, and Leonardo da Vinci drew plans for a parachute. Men lost their lives jumping with umbrella-like machines from roof-tops before the eighteenth century, but the invention of the balloon towards the end of this century stimulated interest in the parachute and provided practical opportunities for drops. The first parachute descent is believed to have been made by the aeronaut J. P. Blanchard who after literally "trying it on the dog", dropped from a balloon in a parachute of his own design in 1793. In 1897, Garnerin made a descent from over 2,000 feet from a balloon and repeated his demonstrations at intervals afterwards.

The parachutes used by these early experimenters were not fixed direct to their bodies, but to a small basket in which they sat. The parachutes themselves, about 23 feet in diameter, were very clumsy, a wooden framework being used to hold them open. The method of dropping was to have the basket and parachute

slung under the balloon, ready to be cut adrift when a suitable height had been reached. The first man actually to save his life by parachute was probably Kuparento, whose balloon took fire when he ascended from Warsaw in 1808. But the idea of using the parachute as a lifebelt of the air is comparatively recent.

It may be wondered why we should devote time to parachutes when dealing with weapons of war. Parachutes are designed for the saving of life rather than its destruction. But there are good reasons. The parachute has been developed as an offensive weapon and in any case its use is still almost entirely confined to military aeroplanes. Parachutes, even if passengers could be instructed in their use and persuaded to use them, would save few lives in civil aviation, where disasters when they occur are often a matter of diving into the sea or driving into a mountain side, rather than the collapse of an aeroplane at considerable height. In time, very large parachutes may be developed, but at present it is test and military pilots who make the greatest use of this apparatus. In commercial flying the pay load often takes precedence of any other form of equipment.

No really important development of the parachute took place between early in the nineteenth century and the end of 1918. Many people find it difficult to believe that parachutes were very little used in the Great War. I believe that no British pilots saved themselves by parachute and it was only towards the end of the War that German pilots began to use them. The modern parachute dates from about 1921 and was not used by the Royal Air Force until 1925. Of the several types,

the Irvin parachute used by the R.A.F. is typical. It consists of a circle of silk 24 feet in diameter with twenty-four lines, each 16 feet long, connecting the harness which is attached to the waist and shoulders of the wearer. The harness is designed so that the wearer can "sit in it", and there is no strain on his body or arms when he is dropping.

The silk itself is flat, but the effect of air pressure upwards and the weight downwards is to produce a hollow hemisphere which traps the air. In the centre of the silk is a small hole to allow some of the air to escape for reducing strain and shock on the parachute or for steadying purposes. The opening device is a flexible cable rip-cord which releases the pins with which the pack is held together. The cord actually releases a very small "pilot" parachute, the pressure of the air on this when it has opened providing the force necessary to pull out the main parachute. The advantages of the pilot parachute is more certain and quicker opening.

A few experimental drops from aeroplanes were made before the War, but considerable difficulty was found in designing a parachute that was compact and yet certain in rapid use. Obviously the old type of balloon parachute which was hung underneath the basket was useless for aeroplanes and a folding model was necessary. The first parachutes used from aeroplanes were carried on the skids, but the parachute did not really become practicable until the folded silk parachute, carried on the back or used as a cushion, was devised. If it is to open easily, careful packing is essential. In practice, parachutes are tested before use by being dropped with dummies, while every modern parachute has a "log"

in which minute details of its use and inspection are recorded. If the parachute is to serve its purpose, reliability is absolutely essential and, in fact, accidents through failure are exceedingly rare.

In the log of a parachute, the person packing it signs his or her name as a token of responsibility. In order to make it possible for inspectors to see quickly the state of a parachute, a "map" of the parachute is kept in the log with numbered panels and any repairs are written on this sheet to save the silk itself being marked. Entries relating to "live" drops are underlined in red. Manufacture is carried out with the same case as that of an aeroplane. All the material used is of the very finest quality, frequently tested.

There are two ways in which the parachute can be used. Either the wearer can climb out on to the fuselage or wing and release his parachute so that wind pressure drags him off the aeroplane when it opens, or he can jump and pull the rip-cord when he has fallen some distance. The first method has the advantage that there is small risk through the shrouds becoming entangled with any part of the aeroplane, and also that it is easier for the beginning than a jump into space. Where a jump is made, the parachutist is taught to count three before pulling the rip-cord in order that there shall be no risk of the parachute opening prematurely and becoming entangled with the aeroplane when it opens. During these three seconds, the parachutist turns somersaults in the air and falls at a speed rapidly accelerating to about 145 m.p.h.

The acceleration reaches a maximum when air resistance equals acceleration and the speed does not

increase further. Indeed it tends to be reduced as the pilot falls into denser air. In delayed jumps made for experimental or spectacular purposes, parachutists have allowed themselves to drop some miles before pulling the rip-cord. These jumps have disproved the old idea that a man falling from a great height is dead before he reaches the ground. The great danger is that continual somersaulting will make the parachutist giddy and cause him to lose control. These delayed jumps have certain practical value for it is certain that if parachutes were extensively used by pilots in war-time, they would be pursued towards the ground by their enemy and machine-gunned. Their chances of escape would be greatly increased if they delayed opening until within 1,000 feet or less of the ground. An additional protective device adopted by some countries is the carrying of smoke bombs by the parachuting pilot. The release of one of these would conceal him from view long enough to escape.

Once his parachute has opened, the dropping pilot is largely at the mercy of the wind, but he can exercise a certain amount of control on his parachute by "spilling" air from it by pulling the shrouds on one side. The modern parachute does not normally spin, and any tendency towards swinging can be counteracted by pulling on the shrouds of the high side at the end of the swing. The same method can be used for increasing the speed of descent, normally about 24 feet a second, so that the parachute shall not overshoot a desired mark. The parachutist attempts to land feet foremost, flexes his knees to take the shock, then as quickly as possible pulls on the shrouds so as to spill all the air

from his parachute and make it collapse before it drags him over the ground. The effect of landing is equivalent to a jump from about nine feet. Various ideas have recently been put forward making it possible to exercise greater control over the direction taken by a parachute and probably the parachutist will eventually be able to choose the spot at which he lands with considerable exactness.

A voyage of 17 miles in a parachute was made some time ago by a French inventor who claims to have "cruised over the English Channel" after jumping from a height of 13,000 feet. He has not disclosed the devices that make possible "sailing", that is rising with upward air currents, and controlling the parachute. The normal parachute drifts some distance, of course, the drift depending upon the particular parachute, the weight, the velocity of the wind, and other factors. A drift of between 900 and 1,300 feet in a descent from 1,000 feet can be expected.

A method by which parachutists might be able to descend some distance from the point of jumping was demonstrated by a Russian some time ago when he jumped with a winged parachute. The wings were detachable, returning to earth by an automatic parachute of their own. The technique is to jump, open the parachute; then to use the wings for sailing as in a glider until the desired spot is reached, when the wings are discarded and a direct descent made.

So far we have considered the parachute primarily as a "lifebelt" to be used when it is necessary to abandon an aeroplane either through engine, structural failure, fire or damage inflicted by an enemy. But in the last

few years the parachute has been developed as a means of transport. It was the Russians who tried this idea of of landing a small army from aeroplanes by means of parachutes. The army could be landed behind the enemy lines, fully equipped with guns and ammunition. At the 1936 manœuvres, Russian airmen carried 150 armed parachutists over the lines of an imaginary enemy and dropped them. In about eight minutes the parachutists had landed, formed into line, and prepared to attack the "enemy" from the rear. Six large machines were used to carry this "army from the skies" and, however experimental, there is no doubt that the demonstration introduced a completely new factor in military tactics.

More recently, operations on a much larger scale have been carried out with as many as 2,000 men being dropped simultaneously. Moreover, the weapons landed were not confined to rifles carried in the hand and ammunition slung on the back. Light guns were dropped by "freight" parachutes, in one instance 150 machine guns and 18 heavier guns being released simultaneously. These were picked up by the troops immediately on landing. There seems no technical reason why larger guns and, it is suggested, even light tanks should not be transported or dropped where required in this way, although any appreciable weight would require a parachute of seemingly absurd dimensions.

Many ideas introduced by the Russian air force have been studied and copied by the leading armies of the world, including the Royal Air Force. In the case of Abyssinia, aeroplanes were used for transporting men and supplies, but the parachute attack has yet to be

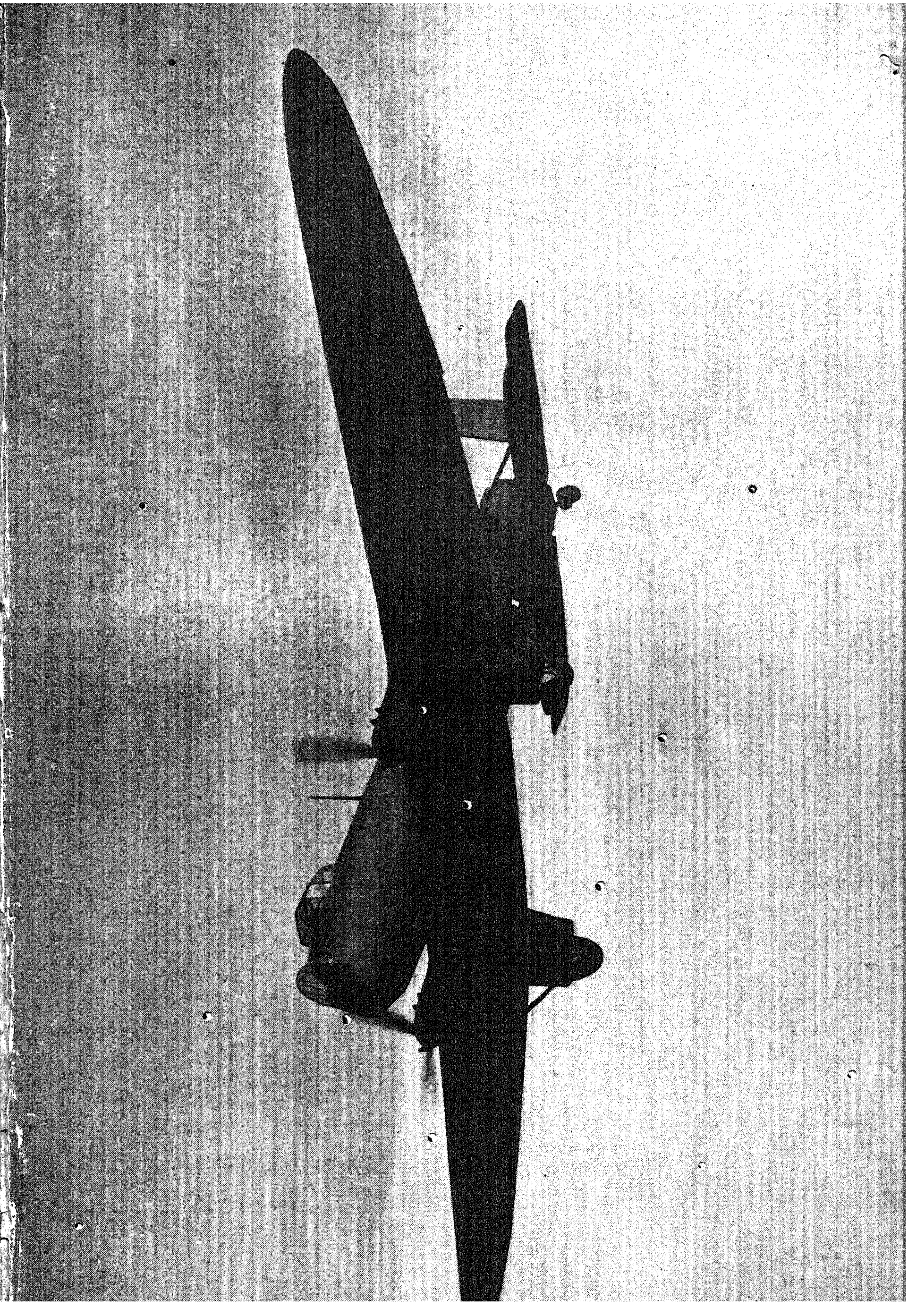
tested in actual warfare. Like so many new threats this example does not appear too serious upon second thoughts. Disconcerting as might be the effect of troops dropped behind the lines, an invasion by this method would require the services of thousands of aeroplanes. From a purely offensive point of view, these might be better employed in carrying explosives. The weight of, say, two thousand men in high explosive could do far more damage than the men themselves. Moreover, it has to be considered whether these large aeroplanes could get behind the enemy lines without being seen. If they were spotted, while they might be able to defend themselves, it is certain that the soldiers they dropped would be machine-gunned while they descended helplessly to earth. No doubt this manœuvre will continue to be practised and may, in a limited field, play some part in future warfare. It does not revolutionize war as has been suggested, but has possibilities for use by spies.

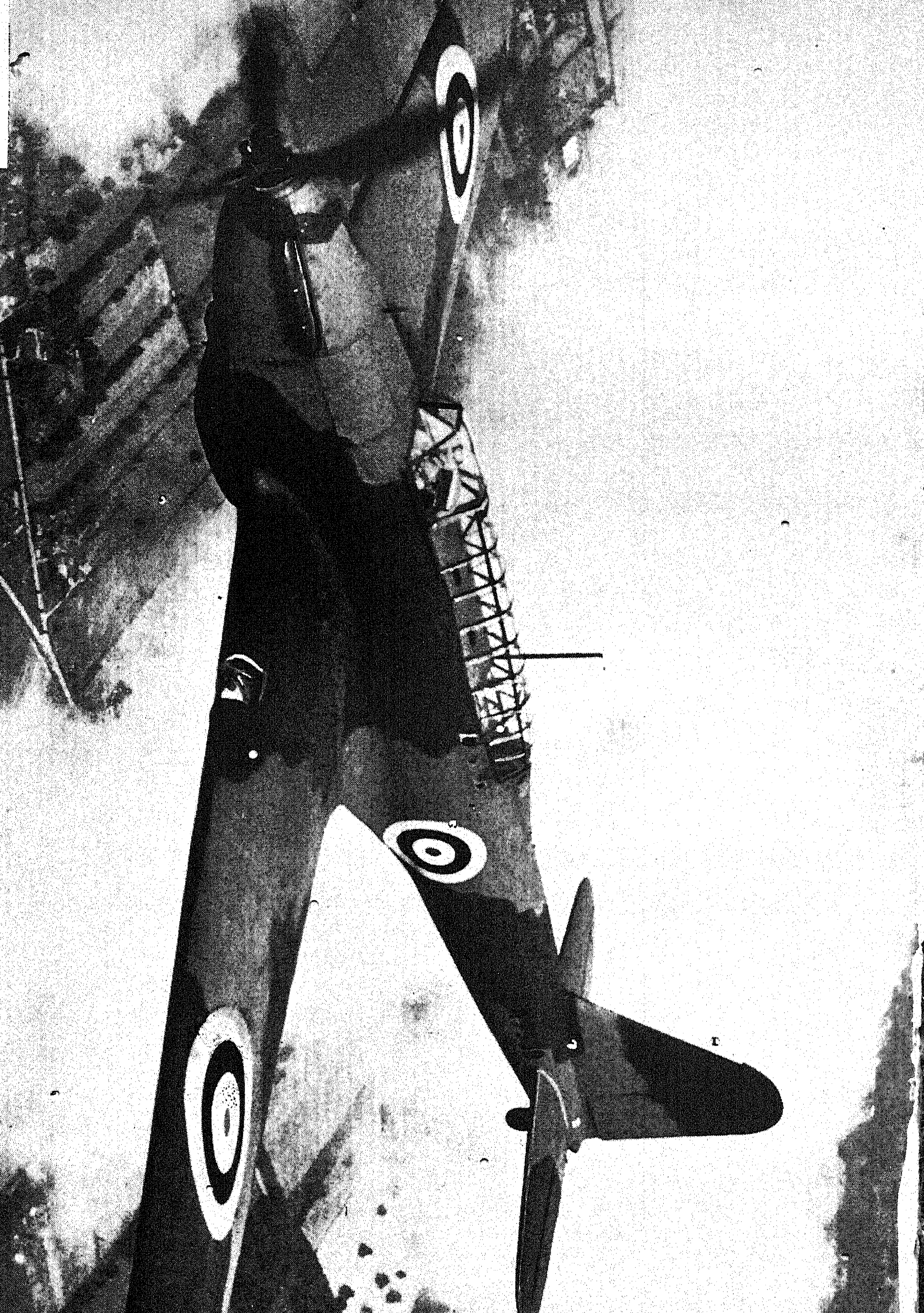
Yet another astonishing application of the parachute as an offensive weapon is reported from Japan, a country where life is not rated highly. The parachutist sits inside a metal chamber shaped like a bomb, carrying several hundred pounds of explosive. But instead of having a fixed rudder like a bomb, the fins are really rudders, this bomb has a movable rudder under the control of the operator who looks out through a glass-protected porthole. The operator wears a parachute and the bomb is dropped from a great height approximately over the target. The operator inside, watching the target coming towards him corrects any mistake in the aiming of the bomb and then, when it is within

a few hundred feet of its objective, pulls a lever which releases the top of the chamber in which he is sitting. The top is carried off by the upward rush of air and the operator jumps out, relying upon his parachute to bring him to earth while the bomb finishes its journey.

Other considerations apart, the possibility of a bomb being guided in this way are small. Even if the bomb were released from a considerable height, the operator would hardly have his hands on the rudder controls before it would be time for him to climb out. Steering a car at over 300 m.p.h. is a difficult task only made possible by natural sighting. A bomb does not fall straight but in a curve, depending on the strength of the wind and speed of the plane. To ask a human operator to guide the bomb on this curve is almost as fantastic as to ask him to launch himself to almost certain death, since the effect of several hundred pounds of high explosive would probably send the parachute down out of control. However, the idea is interesting, for it suggests that inventors are giving considerable attention to the possibilities of the parachute in warfare.

I have mentioned experiments carried out in the dropping of torpedoes by parachute. More likely to have really practical value, is the dropping of sea-mines. Large bombers fitted with mine-laying equipment would be able to circle round a fleet, dropping their loads into the water. On reaching the surface, the parachute would be released, and the mine would set itself to float at a certain depth. This method of attack, likely to immobilize a fleet for some time, has been developed in the U.S.A. The one difficulty is that the





weight of a mine precludes even the largest aeroplane carrying more than a small number. Success with mines, dependent upon chance collision, depends upon numbers, and the damage done by mines dropped by parachute would probably be more psychological than physical.

Many other experiments are now being made with the parachute. It is successfully used for dropping flares to illuminate landing grounds or the positions of enemy troops, it has been applied to certain types of fire bomb and there is a new class of rocket which, upon bursting, discharges a large number of small parachutes fitted with long steel wires. Each wire supports hooks like those upon a fishing line, the idea being that they might entangle themselves in attacking aircraft.

CHAPTER XV

WIRELESS

IT is very probable that the first human signals ever made had some military significance for communication has always played a vital part in warfare. But it is during more recent years that signalling has become all-important. First of all came either the drums of natives or the smoke-puffs of Indians; the information that they could convey being limited to the most simple warnings of the approach of an enemy or call for assistance. Through two thousand years, there was little improvement in signalling. Trumpets and drums were used to sound the advance or the retreat, but for the most part armies relied upon personal messages carried by *aides* or scouts.

Many battles were lost through the inability of a commander to keep in constant touch with his troops and warfare was necessarily slow. It is interesting to note that modern guns would be ineffective but for the development of more convenient methods of signalling at a distance. Gunners of a century ago saw the effect of their shots on the target, whereas to-day guns are fired at ranges which generally necessitate an observer some distance from the battery watching the effect of the fire and signalling back.

At the end of the eighteenth century signalling in warfare was still limited to drums, trumpets and, in a rather clumsy fashion, communication by flags at sea. The Napoleonic Wars stimulated inventiveness and early in the nineteenth century a method of signalling by flags, very similar to that used to-day, was developed by Sir H. Popham; Nelson's historic message at Trafalgar being sent to his fleet by this method. More than a century later, in April, 1918, we find another historic message being sent to a very different fleet on its way to Zebrugge, by the same method, "St. George for Merry England". The science of signalling at sea had been revolutionized, but code flags still retained the great advantage that they could be read instantly by a number of people.

The Napoleonic Wars also saw the development of another new type of signalling, the semaphore. England's fear of invasion led to the erection of a series of towers between London and the South Coast, each equipped with semaphore arms which could repeat a message. This was really a considerable advance on previous long-distance signalling, but still the distance at which signals could be transmitted was limited to the range of the human eye and the system of relaying, as well as the apparatus itself, was very clumsy. This method was not practicable for troops in the field, although semaphore signalling by flags was, for a period, extensively used.

The invention of the telegraph really revolutionized not only signalling but the science of war itself. Here at last was a means by which a general could keep in touch with large bodies of scattered troops, with no

other link than a small wire that could be quickly laid anywhere. Yet so little was the significance of the telegraph for this purpose appreciated that the British naval authorities boldly stated the telegraph did not interest them and that the navy would never require any other method of signalling than that of flags. Many years later one of the War Office experts said that radio would never be of commercial value. Official prejudice dies very hard.

The first recorded use of the telegraph on active service is found in the Crimean War when the trenches were linked with Headquarters by this method. In the Indian Mutiny, the fact that the Government were able to take control of the few telegraph lines has been called one of the deciding factors in the struggle. The telegraph was used in the American Civil War, in the Franco-Prussian War and, indeed, it was the part played by it in the latter that decided Britain to establish the first unit devoted solely to the telegraph.

The establishment and equipment of this one unit really marked the radical change. It consisted of mobile wagons, able to lay wire, to transmit and receive. They were vitally different in purpose from the long-distance wires previously used for keeping armies in touch with each other. The adaptation of this unit to the telephone and other developments followed in due course, but it was slow and for long the army continued to rely largely on visual signalling which was given a new lease of life by the invention of the Morse code.

The system of dots and dashes represented a simplicity far greater than that of code flags. Moreover, the code could be transmitted in a variety of ways.

By day, dots and dashes could be made by waving a flag or by means of a mirror reflecting the sun, the heliograph. By night, the dots or dashes could be made by waving a light or opening and closing a lantern shutter. During the 'sixties these forms of signalling received great attention and were much used in the minor campaigns in which Great Britain was engaged, notably that in Abyssinia.

By 1875, military and naval signalling had reached a point where fairly rapid communication between scattered units was comparatively simple, although both with telgraphic and visual signalling the distance was extremely limited. Field telegraphs were constructed for communication over about four miles, and visual signalling was limited to the range of the eye. In a tropical country, with the heliograph, this meant a considerable distance in favourable conditions. But the necessity for better systems of signalling over greater distances had not really made itself felt, for the range of guns was extremely short and their trajectories comparatively flat. The navy had, perhaps, benefited least of all for, of course, telegraphic communication between the different units or between shore and ship was impossible.

The Navy's turn came with the invention and development of wireless telegraphy. In 1897 Marconi gave his famous demonstration on the roof of the Post Office when, for once, the British naval and military authorities seem to have appreciated the importance of a new invention. The value of wireless telegraphy to the navy was particularly clear and in 1900 orders for the equipment of a number of warships were given.

But before this, wireless had had its baptism of fire. Six wireless transmitting sets were sent out to South Africa in 1899 for the use of troops and ships in the Boer War. In spite of the comparatively elementary state of wireless at that time, the sets proved satisfactory. Various limitations, as well as the advantages of wireless, were discovered, it being soon realized that in any army there would have to be a combination of the three methods of signalling; personal carrying of messages, visual signalling, and communication by wire or wireless.

The Great War saw a tremendous development of military signalling and proved, if proof were needed, that battles could be won or lost by the efficiency of the signallers. It is said that Germany would never have received her check on the Marne in 1914 if her plans for communication between the armies and headquarters by wireless had worked out. The defeat of the Russians in Eastern Europe was probably not a little due to the failure of the military experts to realize that vast armies could only be efficiently commanded by the widest use of scientific methods of signalling.

On land, wireless was comparatively little used owing to the impossibility of setting up delicate transmitters in advanced positions subject to heavy bombardment. Indeed, it is interesting to note that as the armies dug themselves in, employing more and more artillery, they had to rely more on the age-old method of communication, the personally carried message. Shells were exceeding destructive of wire and even burying the wires several feet deep did not prevent them being cut. Communication by rocket, already mentioned under the

subject of chemical warfare, was developed and very wide use was made of carrier pigeons.

Pigeons for carrying messages had been used by armies in the distant past, but the Great War was the first in which they were tried in large quantities. They proved exceedingly useful, if not indispensable, in special circumstances. An aeroplane forced down on the sea is unable to use its wireless apparatus and baskets of pigeons were carried by aircraft engaged in coastal patrols. In an emergency these were released at intervals to summon assistance and were instrumental in saving many lives. Pigeons were used in the front lines for conveying messages back to headquarters when it was impossible to communicate by other methods. The very powerful homing instinct of the birds made them fly through terrible conditions, even after being wounded. In a number of cases pigeons struggled in with their messages although shot in several places and on the point of death. It may not, perhaps, be pleasant to think that Man has had to harness the sexual instincts of birds to enable him to destroy his fellow-creatures, but as I have several times emphasized, war is a brutal business. If we allowed for the elementary forms of decency we most certainly would not fight at all.

Pigeons carried their messages in small aluminium containers, weighing a fraction of an ounce, attached to their legs. Where they were seen, they were shot at by the enemy, of course, but comparatively few were deliberately brought down. The Germans brought to their aid a natural enemy of the pigeon, the falcon, using these birds to pursue and destroy enemy pigeons. The

French replied to this move with the ingenious idea of fitting a whistle to the wings of their pigeons. When the bird was in flight, the pressure of the air sounded the whistle, which frightened the falcons.

An interesting development of the use of pigeons, although it was not directly concerned with signalling, was the invention of small automatic cameras which, fixed under the body of a bird, took pictures of the land below. The cameras depended, at first, upon a shutter actuated at intervals by a bulb into which air leaked slowly. This device enabled six pictures to be taken on a flight, and had the advantage over photographs taken from an aeroplane that no risk of human life was involved while the pigeon, being so small, could escape attention where an aeroplane was certain to be noticed. The photographs, of course, did not have the quality of those taken by a human operator, but in a long strip of exposures, the chances were that there would be two or three which would cover the desired area. These cameras have been considerably improved since the War through the development of improved light alloys.

Some 100,000 pigeons were used by the British for message-carrying and other countries employed similar numbers. The service rendered by these pigeons led to the establishment of dove-cotes as part of the general equipment of the major armies. In Britain a "skeleton" force has been under the charge of the R.A.F., capable of almost immediate expansion in the event of hostilities to an army of 500,000 birds. The great popularity of pigeon-racing as a sport makes this comparatively easy in England. In the United States,

pigeons are attached to the Corps of Signals, with a special training station at Fort Monmouth. There are, of course, many forms of sport which are officially encouraged for their supposed value in wartime.

Science is important in the breeding and training of pigeons. Although homing is an instinct, it is one that must be developed. To get the most promising material, scientific breeding is used, parents being selected for their strength, stamina, speed and homing instinct. Normally, pigeons will not fly during darkness. Their instinct makes them roost for the night. United States experts by carefully selecting birds for breeding and training them have managed to overcome this primary instinct. These birds have flown fifty miles or more in darkness. They are trained by being kept in darkness during the day and released only at dusk so that they gradually come to regard twilight or darkness as the natural time to be abroad.

We might inquire into what it is that makes a pigeon fly home through any weather or storm of shot and shell. The general answer given is that it is "instinct", but this does not explain how the birds are able to find their way over unknown country. The motive driving them is instinct to get back to their young, the mother bird is a more successful homer than the male. But how they find their way remains a mystery. No doubt certain landmarks guide them, but this can only be in the later stages of their journey, for a pigeon will find its way over hundreds of miles of sea or land which it has never seen before. Possibly some form of direct integration can explain a phenomenon which is little understood.

It has been suggested that birds make the sun their "compass", which seems quite possible. Another idea was put forward that they have some organ very sensitive to the magnetism of the earth and, in effect, are guided by an induction compass. Some support for this theory is the fact that pigeons have been noticed to be affected by wireless transmitters. In the neighbourhood of a transmitter, a pigeon which is released will circle uncertainly as if its "bearings" had been destroyed. If this proves to be the case, no doubt in time wireless will be used deliberately for guiding pigeons to the wrong place, or so confusing them that they are unable to find their lofts.

It is strange that, after centuries of invention, Man has had to fall back on one of the oldest methods of communication. But war produces artificial conditions. The telegraph, telephone or wireless are, and must for many years remain, comparatively delicate mechanisms. Moreover, they call for wires, batteries and other encumbrances. The military ask the wireless engineer to provide for them a wireless transmitter that is reasonably robust and efficient, but yet sufficiently light or portable to be used in the front line. Tremendous advances have been made in recent years; small tanks and aeroplanes can now carry receiving apparatus which is efficient under the hardest use. "One man" portable sets are also being developed but they are inclined to fail by lack of secrecy.

The transformation that wireless has brought to warfare can be seen when a number of tanks or aeroplanes are manœuvring. There are no trumpet calls, they could not be heard in the din of a modern battle, every

order is given through the microphone and received in headphones. It is thus possible for a commander to speak not only to all the units under his command simultaneously, but to give individual orders. This principle is also demonstrated by the system of calling police cars. A single transmitter can control the movements of hundreds of cars over an area of many square miles. In the air, messages giving the position of enemy squadrons which have been detected by other aeroplanes or land forces can be transmitted to fighter squadrons. The value of this in warfare has yet to be tested, but it is obvious that it offers a real opportunity to intercept raiding bombers; in great contrast to the methods used in the last war where intercepting aircraft had to take off and search a huge area of sky with very small chance of finding anything.

The great disadvantage of wireless is, of course, that it lacks secrecy and while this can be overcome to some degree by the use of codes or "scrambling", these methods necessitate more elaborate apparatus. Actually, electrical apparatus during the Great War was used for "tapping" enemy communications by wire through induction. Messages being transmitted in telephone or telegraph wires could be "tapped" at a distance of several thousand yards by very sensitive instruments; this explained much of the knowledge of each other's plans which the two sides had and contributed to conditions of stalemate. Engineers tried to counteract this by using metallic circuits instead of an earth return, but the fact remained that in favourable conditions, almost any message transmitted in the front lines could be heard by the enemy.

Important as will be the art of wireless communication in any future war, the probability is that it will be also used for purposes of control. During the Great War I designed and demonstrated the control of a small aeroplane, entirely by wireless. On Salisbury Plain it was launched by compressed air and flew without any pilot at the controls. The movements of throttle, rudder and ailerons were controlled by a wireless set mounted in a lorry. The first flight was very brief, ending, incidentally, with the aeroplane putting the watching military experts to flight by diving straight at them; but it was a beginning. Wireless control has now developed to the stage where it is possible to control not only aeroplanes, but battleships and tanks from a distance.

The main principles of wireless control are simple. Wireless signals are a form of energy. Whether we turn this energy into sound through a loudspeaker, into light, by means of a cathode ray tube as in television, or into mechanical movement, is a matter of choice. Simple signals are usually sufficient for control, a particular signal actuating a coded mechanism which in turn moves the controls. It is important to note that the wireless signals do not provide the energy to move the rudder, throttle, or whatever it may be. Science has not yet been able to devise a means of transmitting sufficient energy to move the rudder of an aeroplane. The power for the actual movements has to be provided locally by electric motors or some similar mechanism and all that the wireless signals do is to switch this mechanism on or off. In an ordinary loudspeaker, the wireless waves do not themselves produce

the energy to make sound waves but control the vibrations of the speaker, the energy coming from the local high-tension battery or main supply. Electrical energy at a distance by radio is an unpleasant improvement reserved for wars of the future.

What happens in a radio-controlled aeroplane is that a signal is received, amplified, and, in accordance with its type or "code", then sets in motion a motor controlling the rudder, throttle, or ailerons. There is no reason, of course, why a control should not be arranged for the release of bombs or the taking of photographs. In a wireless controlled battleship, such as the *Centurion* which has been used by the Fleet for target practice, the signals in the same way are amplified and then passed to the appropriate controlling mechanism, in this case, considerably more powerful. A wireless tank works on exactly the same principle, the only difference being in the mechanism set in motion by the controlling motors.

The distance from which control can be exercised is limited, in theory only by the distance at which signals can be received and, in fact, mechanism in Australia has been set in motion by wireless signals sent out from Britain. In practice, the field is at present much more limited, and in the "Queen Bee" radio-controlled aeroplane the range is about ten miles. The receiving set must be adjusted before the controlled aeroplane or ship is let loose, the fine adjustments which a human wireless operator can make in accordance with changing conditions are not possible. Probably the range at which remote radio-control is certain, is at present under twenty miles, but even at this distance, it may

prove an exceedingly effective weapon if the enemy are unable to "jam" its signals.

To every weapon there is a defence and in the case of wireless control this defence is the possibility of jamming the signals which are controlling the aeroplane or battleship. The battle of the future may well depend upon who is able to destroy the enemy's wireless station first and it is certain that great efforts will be made to discover the "code" of signals so that, for instance, while the owner of an aeroplane is signalling it to move its rudder to the left, the enemy is sending out signals which will have the effect of making it turn right.

Television is also being adapted to war needs. It is not possible to reveal how far experiments have gone, but it can be said that the stage has been reached when an aeroplane can send back to headquarters a continuous picture of the ground below it which can be shown on a television screen and this entirely without human intervention. Distance and position signals can also be transmitted. The range of television is very small, but an aeroplane capable of showing troop movements, even within a few miles, would be of tremendous value. Moreover, whereas unless the human observer is able to signal or to return with his records, his effort is wasted; with the television aeroplane it would be of no consequence if it were eventually shot down since the vital information would have been already received at headquarters.

That radio-control is no longer in an infant stage, although it will remain in the experimental stage for a long period, is shown by the success of the "Queen

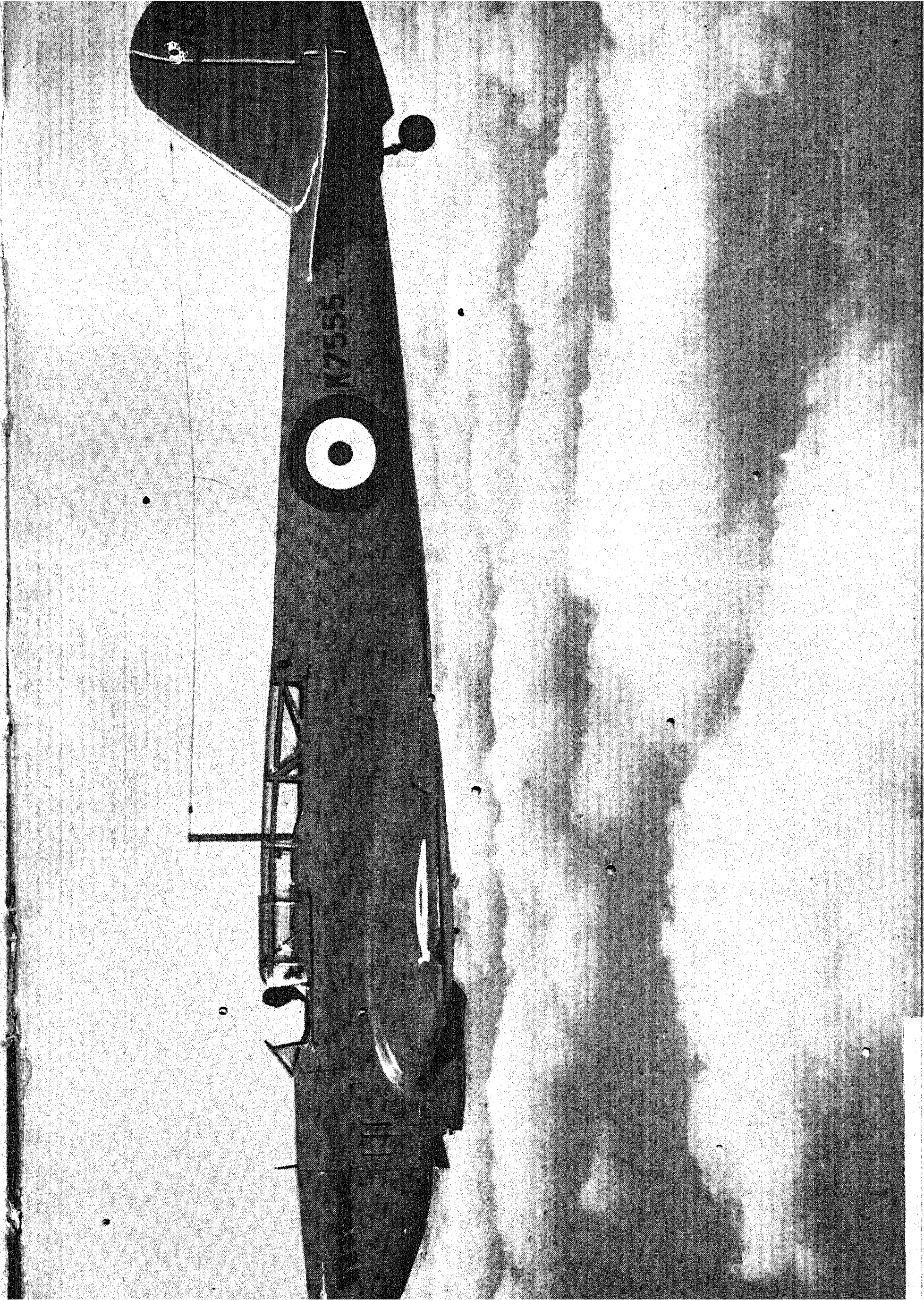
Bee" aeroplane and the *Centurion* battleship for practice. The "Queen Bee" is controlled from a battleship and has proved itself able to perform any ordinary manœuvre in the air while being used as a target for anti-aircraft guns, at heights up to 15,000 feet. The *Centurion* is controlled from a distance of some miles by a destroyer; she is able to increase or decrease speed, turn in either direction and perform the ordinary manœuvres of a battleship under fire. The signal-receiving mechanism, of course, is buried deep in the ship to minimize the chances of it being destroyed by shell-fire and duplicate aerials for receiving the controlling signals are arranged so that the destruction of one does not end the usefulness of the ship. The controls are exceedingly simple, in the case of the "Queen Bee" merely touching buttons like those on a "press button" wireless receiver, being sufficient to make the aeroplane several miles away perform any manœuvre.

In future wars, wireless will have two completely distinct functions. In addition to being used by the armed forces for communication and control in the way I have described, it will be used for the information, entertainment and education of the general public. Apart from the use of telephone wires, exact plans are made for broadcasting in the event of hostilities breaking out, but I doubt whether these plans will ever envisage all the possibilities. The importance of broadcasting from a military point of view was appreciated as soon as the number of listeners began to increase by thousands a week. Two points immediately occurred to the experts. First of all, the acquisition of receiving

sets by millions of ordinary people meant that military communications could be received by anyone and that spies would be exceedingly hard to detect, since the possession of a wireless receiver would no longer be a matter for suspicion.

Even more important, perhaps, it is now appreciated that enemy broadcasts can be received and the war won by propaganda. The broadcast of false news calculated to alarm or dishearten the civilian population by the enemy might prove more potent than high explosive. During the Great War there had been a number of instances of battles decided by propaganda and the dissemination of false news in print behind the lines. Broadcasting provided a simpler method of propaganda and the authorities, half-afraid of this new factor in warfare, more or less decided that in the event of hostilities it would be necessary to confiscate all receivers from the general public. The Government, of course, have always kept wireless under its control. The average listener thinks of his "licence" in terms of paying for entertainment. Actually, it was mostly the military importance of wireless that led to a system of licensing, long before broadcasting as we know it was in being.

In recent years, the attitude of the Government has changed and no confiscation of wireless sets during a war could prove really effective. There are a number of reasons for revision. First of all, confiscation would be impossible. To visit some ten million homes and make sure that no set was concealed in a cellar or cupboard would take an army of inspectors several months. Confiscation would not prevent listen-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ing, for anyone with an elementary knowledge of wireless can now construct a simple but effective receiver of such things as are found in every house. At the same time, because listening would be forbidden, it would become more desirable, that is elementary psychology. The atmosphere of secrecy, of the forbidden set in a cellar, would certainly make enemy propaganda far more effective.

The policy is now more positive rather than negative. The maximum use of the great resources of British broadcasting can be used for issuing official instructions, for directing public opinion both at home and abroad, and for keeping up the morale and spirit of the "home front", as well, perhaps, as for continuing the education of evacuated children who would be unable to go to school. For issuing instructions alone, broadcasting is now indispensable. The clumsy business of calling-up papers, written instructions, and proclamations by picturesque, but out-of-date, town criers, can be superceded by a scientific device which enables instructions to be issued to almost the entire population by one man, who maybe hidden away safely from enemy aeroplanes in some deep shelter or at a lonely spot in the country.

It may have been the General Strike that changed the official viewpoint. But for broadcasting, the General Strike might have developed into civil war and would certainly have been more serious. On the outbreak of hostilities a lightning raid might prevent the newspapers being issued properly for some days. Newspapers were not published during the early days of the General Strike and, but for broadcasting, the

public would have been quite unaware of what was happening. The first result of ignorance in moments of tension is generally panic. Wireless enabled this panic to be avoided, and this must always be its function at the outbreak of war.

Apart from instructions, broadcasting will be used for propaganda. This need not be the dissemination of untruths, but rather the telling of the truth with restraint. Propaganda is useless if it is not believed, and no one is so distrusted as the known liar. Propaganda, therefore, has to be handled with extreme care. Fortunately the British Broadcasting authorities have pursued a policy of responsibility that renders it simple for the official broadcasters in the time of war to win the confidence of the public. Certain countries which have used broadcasting unscrupulously for the distortion or undue suppression of truth in peace-time may regret this if they are involved in hostilities. There is an old story about the person who cried "Wolf" too often.

Perhaps few people have noticed it, but there is a growing tendency to believe anything that is broadcast. "Seeing it in print" used to be a way of emphasizing the truth of a statement. But to-day, perhaps as the result of the divergent news of the different newspapers, it is hearing something on the air that is often the hallmark of truth. Another reason for this is that the spoken word is still more potent than that which is printed. We have only to remember the panic that followed the broadcasting of a humorous news bulletin in England and of a Martian play in the U.S.A., to realize the enormous influence of radio.

The power of broadcasting to guide public opinion on a national scale during a crisis has already been twice dramatically demonstrated since the Great War. In the Socialist revolution in Vienna in 1934, the Government, by broadcasting statements that it was a purely local affair, giving very little trouble, prevented the revolution from spreading. People who might have joined in were discouraged from supporting a cause that was stated to be already lost. Then again, at the beginning of the Spanish War, broadcasts prevented thousands, perhaps millions, from joining the Republican forces by persuading them that the rising had been successful and that the war was as good as over. Of course, in time the people learned the truth and joined, but the delay caused by the wireless seems to have been a very potent factor in the ultimate victory of the "Nationalists".

These two incidents reveal that in a modern war, a wireless transmitter may be a more important weapon than a battleship or a big gun. The enemy would undoubtedly make broadcasting stations one of their targets. It is part of air raid precautions to prepare stations for air raids and while, by reason of the necessary wires and delicate electrical instruments, transmitters must be open to damage, it is possible to arrange duplicate control rooms in shelters proof against even direct hits. The actual transmitting aerials must, of course, be above ground and by their size provide a landmark, but fortunately it is not necessary to have aerials near the studios. They can be placed in a remote country district and connected by landline with microphones at convenient spots.

Broadcasting House has been carefully studied from the point of view of air raids and the necessary changes made. There is a basement containing a duplicate control room, with gas-proof doors and air conditioning. The studios themselves, because of the construction of the building for acoustical purposes, are fairly safe; it is doubtful whether a direct hit would wreck them all. The connecting cables with transmitters are underground. Their destruction would be entirely fortuitous and it is unlikely that all would be destroyed at once. Modern radio receivers are able to receive clearly from considerable distances and therefore the destruction of one transmitter would simply mean that people would turn to others. The transmitters themselves are independent of outside sources of power, local electric power being provided. If the underground cables should be destroyed, it would still be possible to send broadcasts to the transmitters by short wave radio, and no doubt steps have been taken to make this possible in an emergency.

Ten years ago the experts would probably have said that the maintenance of broadcasting in the face of determined and repeated air raids would be difficult, if not impossible. Technical progress in the last decade has brought the odds round in favour of transmission being maintained. The greatest difficulty might be at the receiving end. The majority of modern receivers get their power from the mains and the destruction of a large power station might make a large area "deaf" to broadcasts. This can be overcome by the storage of battery receivers for emergencies and also by the use of receivers taking their signals through the telephone

circuits. It is not necessary to use the ether for the transmission of signals, the current variations can be transmitted through the ordinary telephone line and received by a special receiver which is actually simpler than the ordinary wireless set. By the necessary organization water and gas pipes could also be used.

The Post Office have recently adopted a policy of making this service widely available and no doubt in the course of time an increasing number of people will receive their programmes in this way. In peace-time it has the advantage of freedom from interference and in war-time would have the additional advantage that it could not be jammed by enemy stations. In years to come, the taking of a plebiscite might be rendered very simple if an electrical "yes" or "no" could be recorded from every house in the land.

The question of jamming is one that remains open. An enemy might decide to prevent broadcasts being made by transmitting on the same wave length and either drowning or "shouting down" our stations. This seems, at first thought, an obvious step to take. But it is by no means certain that it will happen. For one thing, other stations would obviously retaliate and while an enemy station might be able to prevent others broadcasting, it would be unable to broadcast itself. In a war of jamming, victory would go to the best-equipped nation, and in this respect the network built up by the B.B.C., entirely for peace-time purposes, would be of immense value. Then again, effective jamming is not easy at a distance. Nation A might be able to jam signals from a transmitter in Nation B when they were being received by listeners in Nation A, but would find

it difficult to prevent them being received in Nation B. The use of jamming is, therefore, likely to be limited to preventing enemy propaganda being received. It is not likely to be used, or at any rate not likely to be effective, in preventing broadcasts for home consumption being heard in the ordinary way.

There are in Great Britain a considerable number of amateurs with transmitting licences. At the beginning of the Great War the Government silenced the few amateurs then in existence. They are not likely to adopt exactly the same plan in the future for these private stations would be exceedingly useful for emergency purposes. The probability is that spies in all countries have arranged to use small transmitters for sending their messages. A transmitter can easily be concealed. Fortunately, it can also be fairly easily tracked down. Once the "pirate" began to transmit, its position would be detected, however well the set and aerial might be disguised.

The method of tracking is not complicated. A mobile receiver with a directional aerial finds the direction from which the transmission is coming. It then moves to another spot and makes another observation. Directional lines from these two receptions are drawn and their meeting-point is the position of the transmitter. This method is used every day by aeroplanes to get their bearings and it is certain that a pirate or spy transmitter, unless it were itself mounted in a mobile van, would be detected within a matter of hours. Spies are likely, therefore, to have to fall back on the older methods for conveying their messages.

In the event of a "spy" transmitter being detected,

the Government would be more likely to use it for sending false information than to close it down. Of course, the majority of messages in war-time would be sent in code, but with modern scientific methods of solving ciphers, the question is not generally whether a code can be discovered, but how long it will take to decipher. During the Great War some of the greatest mathematical brains in the country were employed in deciphering enemy messages and their success was astonishing. Rarely did a code, however frequently it was changed, defeat them for more than a few minutes.

The disadvantage of wireless as a means of communication is that it can be received by almost anyone. There is no privacy. It is possible, however, to "scramble" messages in such a way that they can only be unscrambled by someone "in the know". Scrambling, amounts to an electrical cipher, and while the detection of the particular type of mixing being used as a different and, possibly, a more difficult problem than the solution of a word code, it will not prove impossible.

We have considered wireless entirely as a weapon of war and I hope that its very real potency has been made very clear. This great invention, designed to provide communication between ships at sea and to save life, has been turned, like so many others, to warlike purposes. From the humane point of view, wireless is the best of all weapons. It conquers people's minds for a time rather than destroying their bodies. It may be the means of making a whole nation submit without blood being shed. The ability of a country to win a war will depend not a little upon its strength of mind, upon what some people call "morale". The probability is,

therefore, that victory will go to the people who believe their cause is just, have a high standard of education and great confidence in themselves. In peace-time, radio is one of the most effective weapons for the prevention of war, for it can disseminate the truth to the maximum number and truth is wonderfully effective in solving the most difficult of problems.

All wars have been due to belief in certain false viewpoints, generally by both sides. An "International Transmitter", broadcasting the truth, the whole truth and nothing but the truth, would be a better guarantee of peace than an international police force. The impossibility lies, in the present stage of human development, in finding the superman who, without self interest, could see truth through a fog of conflicting interests, ideals, and alleged facts. But we might make a beginning. The power of suggestion is tremendous and the continuous suggestion of peace by radio transmitters would, if unable to stop the next war, act as some slight insurance by delaying the "war after next".

CHAPTER XVI

THE FUTURE

TO A CERTAIN DEGREE I have already visualized the future of war in dealing with modern armaments and their development. The future, as far as war is concerned, is believed by many people to be all too near, and if this should be true it will be fought with the weapons of to-day. In peace-time the evolution of new weapons is necessarily slow; scientific development is not enough for apparatus which is to be used by relatively inexperienced men. This may appear unprogressive, but in fact, the problems are very much the same as those faced by the manufacturer of a motor car. When he has decided to make a new model, he must instal special plant to enable the new parts to be manufactured or assembled, and he must arrange for supplies of raw materials. This must be done many months before the first car is to be distributed, and involves a huge investment of money. The investment is worthwhile because the manufacturer knows that before the car is obsolete, he will have sold a sufficient number to the public to ensure his profits.

This new car may be theoretically obsolete by the time it reaches production, for progress is continuous,

and it is certain that some later improvements will have been devised. Abolish the new model, put yet another into the stage of design, when exactly the same position is reached. Still more discoveries will have made it out-of-date. Every motor-car is, therefore, something of a compromise, and is necessarily some distance behind the latest developments.

Very much the same is true of armaments, except that the vast number of arms required means that the time-lag between production and discovery is even greater. Suppose, for example, that you have invented a new rifle, more effective than that used to-day, and equally able to withstand the difficult conditions of active service. The first step would be that of testing under the most varied conditions such as might be encountered in the field which would involve firing many thousands of shots and take some months. If the army decided to adopt it, half a million weapons might be needed as a first order, with arrangements for rapid replacement in the event of war. This would imply the making of a large number of new dyes and other manufacturing apparatus; altogether it would, perhaps, be as much as three or four years before a whole army could be equipped.

Those responsible have, therefore, to compromise by adopting a standard arm for a period of years. At the end of this period it will be replaced. This is particularly necessary in arms required in vast quantities such as rifles, grenades, or gas masks. In the case of large guns and tanks, production does not need to be on such a large scale so that new models may be put into production more frequently. War is a great stimulant to novelty,

not because inventors are vastly more active, they are always busy with new ideas for warfare, but because normal conditions are swept aside and a new design may be put into mass-production within a few days of being approved. It is generally, therefore, during a war that new weapons come to the front. In the four years of the Great War greater technical advances were made than had been accomplished in the previous fifty years. A hundred new weapons with counter-weapons of real importance were put into mass-production, from Mills bombs or Stokes mortars to tanks and paravanes.

I make this point because many people believe it is the conservatism of military thought alone that prevents the adoption of new weapons almost every day. We must admit that military leaders, since the beginning of time, seem to have suffered from prejudice and that it has generally taken a major war or the death of many thousand soldiers to alter their ideas. Army drill is still founded on the time when men went into battle shoulder to shoulder, keeping step, with bands playing to keep up their courage. The drill manual instructs a soldier in just about everything he would not be expected to do under actual conditions of modern warfare. We are told, of course, that although drill is no longer necessary from a practical viewpoint, it is necessary to imbue discipline and courage. Much of this is sheer nonsense, dating from the time when soldiers had not the faintest idea what they were fighting for, and, in most cases, cared still less.

The standard of intelligence to-day is definitely higher, and true discipline comes from belief in the

reason for certain actions. There is no need to give the research chemists of a large manufacturer one hour's drill, mental or physical, every day, lest they might become so undisciplined as to wander into some strange branch of private research. The soldier, to-day, has to fight as an individual, often some distance away from his nearest fellow, at best, simply as a member of a small group. A private must have the same imagination and ability to act on his own as was necessary to an officer a century ago. I suggest that forming fours, or threes, as it may be to-day, dressing by the right and so on, does little to encourage the desired qualities. Possibly the next war will reveal this fault, when it is too late. It may well show that the intelligent citizen, with a moderate amount of knowledge, is capable of acting effectively in defence, even when he breaks the heart of a drill-sergeant on the parade ground. This was almost painfully true in the Boer War and is worthy of note even by the most enthusiastic advocate of such things as goose-stepping or exaggerated detail in formation flying.

I have seen the view put forward that weapons will soon be invented which will be so destructive or painful that no one will dare to fight and that war will then cease to be an arbiter simply because no one will dare to put it to the test. I wish that I could agree with either the chance of invention of such a destructive method, or that it would ever be possible to discourage some people from fighting. The facts are all against either possibility. If we are not discouraged by flame-throwers, gas, high explosive, or even germ warfare, I doubt whether there remains anything

sufficiently terrible to frighten us from war. Actually the whole history of warfare suggests that a new and more powerful weapon only helps to produce a new and more powerful defence. The percentage of casualties in a modern battle is far lower than those of ancient days, although the total casualties may be greater owing to the number of men engaged.

Of all the weapons forecast for the future, the death ray is that heard of most frequently in its appeal to the popular imagination. There are those who will tell that the death ray has been invented and about one inventor a week offers to give the Government a demonstration of his own particular design. Personally, I am of the opinion that nothing approaching the popular conception of the death ray has yet been invented and I do not anticipate its appearance for some considerable time, not, perhaps, for another fifty years. I make this estimate with reserve, however, for chance plays some part in invention as far as the moment of completion is concerned.

The usual ray of fiction is something that is projected like a searchlight, to destroy everything in its path, presumably shrivelling it up as if by fire. Milder versions of the death ray call for a ray that will in some way burn out the magneto or other electrical equipment of an aeroplane and put it out of control. Now any ray of this kind presupposes the ability to transmit energy via the ether. Broadcasting has made everyone familiar with the transmission of energy in the ether, but because of the "power" of a modern loudspeaker many people are completely deceived as to the amount of energy that is received. A transmitter may use a

power of 500 kilowatts, but the amount picked up by a receiving set is minute, hardly sufficient to move a fly a distance of an inch and certainly not enough to melt a thin wire. Most of the energy is dissipated in many other directions. Moreover, this is received on a carefully prepared aerial with an earth to complete the circuit. The energy received is not sufficient to vibrate the diaphragms of a loudspeaker without amplification by local sources of power. The difficulty of the inventor concerned with a death ray is that no enemy is likely to dangle a conveniently insulated aerial from his plane to ensure that all available energy enters the magneto; he is even less likely to have several stages of amplification to boost the energy received.

I should be quite ready to destroy an aeroplane by means of a ray, provided I were allowed to choose my aeroplane and make the conditions of the test. There would be no difficulty in sending the plane down in flames at the mere touch of a key operating the "death" ray, because I should arrange a receiving set which, instead of turning the energy into sound, directed it towards a fuse, or some part of the engine. Inventors have successfully demonstrated the stopping of motor-cycle engines at short distances by means of a "ray", but they overlooked a point that should be obvious to anyone: the enemy are not going to arrange their engines so that they can be so easily stopped in this way. On the contrary, they are likely to shield engines with metal, and as it is very easy to secure this kind of insulation, it would be impracticable to reach them with any ray carrying appreciable power.

It seems essential for the death ray to make all the

energy transmitted travel by a very limited path instead of spreading over a wide area. We want the equivalent of the parabolic mirror which concentrates the searchlight's beam. Such aerials are used on long-distance wireless transmitters, but they cannot be made to transmit a beam in the true sense of the word. The projection is more in the shape of a fan and to signal to a particular spot so that no one, other than in the direct path, could pick up the signals, remains one of the great dreams for the radio engineer.

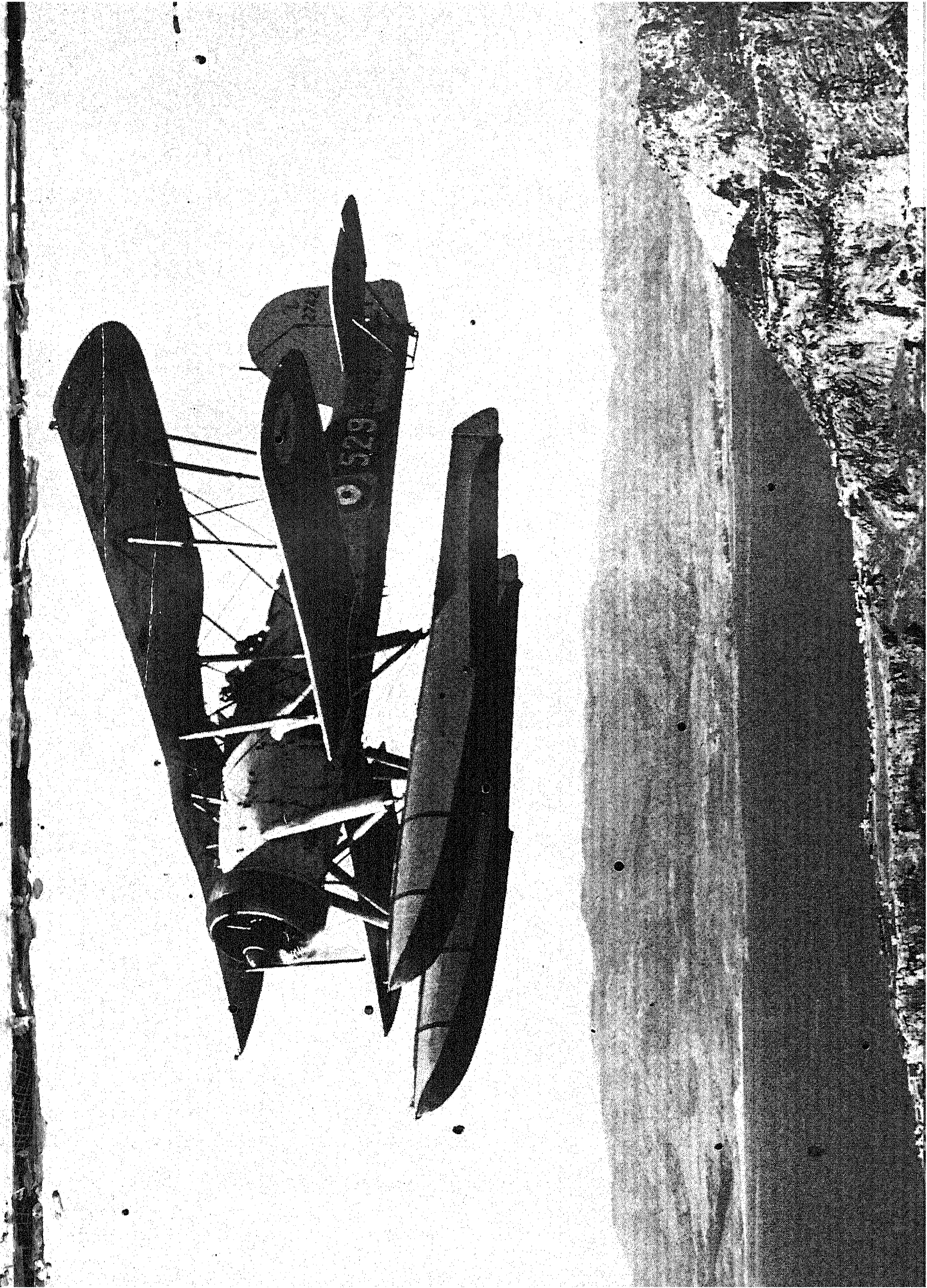
Realization of this ideal would have a tremendous effect on wireless as a means of communication. I would go so far as to say that it would be far more important than a potential death ray and incomparably easier to produce. The inventor would certainly not have to worry about collecting a few thousand pounds from the Government for his invention, the commercial communication companies would be glad to buy it, for apart from saving several million pounds a year, the invention would open up vast new fields for commercial exploitation. The transmission of energy for heating and lighting our homes without the use of wires might also be within easy reach. Radio for motor cars will not mean radio energy for very many years. The day when induction transmission cables are laid beneath our main roads is still in the far dim future.

At present, inventors seem to be concentrating on the principle that while energy cannot be sent in a wireless beam, it may be sent along another path, prepared in the air. Inventors keep their secrets, of course, but the general idea is either to ionize the path along which the energy travels or to use some form

of searchlight to act as the initial carrier. The designer, in fact, tries to provide a "wire" to carry the energy, the difference being that in these cases the wires are invisible or consist of bands of air that are continuously treated to make them attractive paths to an ether transmission. It may well be along these lines that the death ray problem will eventually be solved, but it will then be open to the other side to prepare their defences. Fortunately, the relative military and commercial values of the invention will still remain.

I have talked to many inventors who thought they were on the track of a death ray, but none of them have been quite clear about what the energy was going to do, even when if they had been able to transmit it in large quantities to an approaching aeroplane. Some thought that it would cause electrocution, but assuming that the equivalent of 5,000 volts could be sent at high pressure, the problem of making it circulate through the pilot's body remains. In the case of legal electrocution, when the executioner has every facility, he must have special electrodes which are damped, and he must shave the skin of his victim to ensure "perfect" results. Others thought that the ether waves would act directly, and talked of the effect of certain bands in raising the body temperature.

It is true that short waves will raise the temperature. But it must be remembered that when this cure is used in hospitals, the patient is surrounded by special apparatus, lies perfectly still for a considerable period and is subjected to intensive bombardment at a range of a few inches. Unfortunately, enemy pilots are not likely to be so obliging. On the contrary, they are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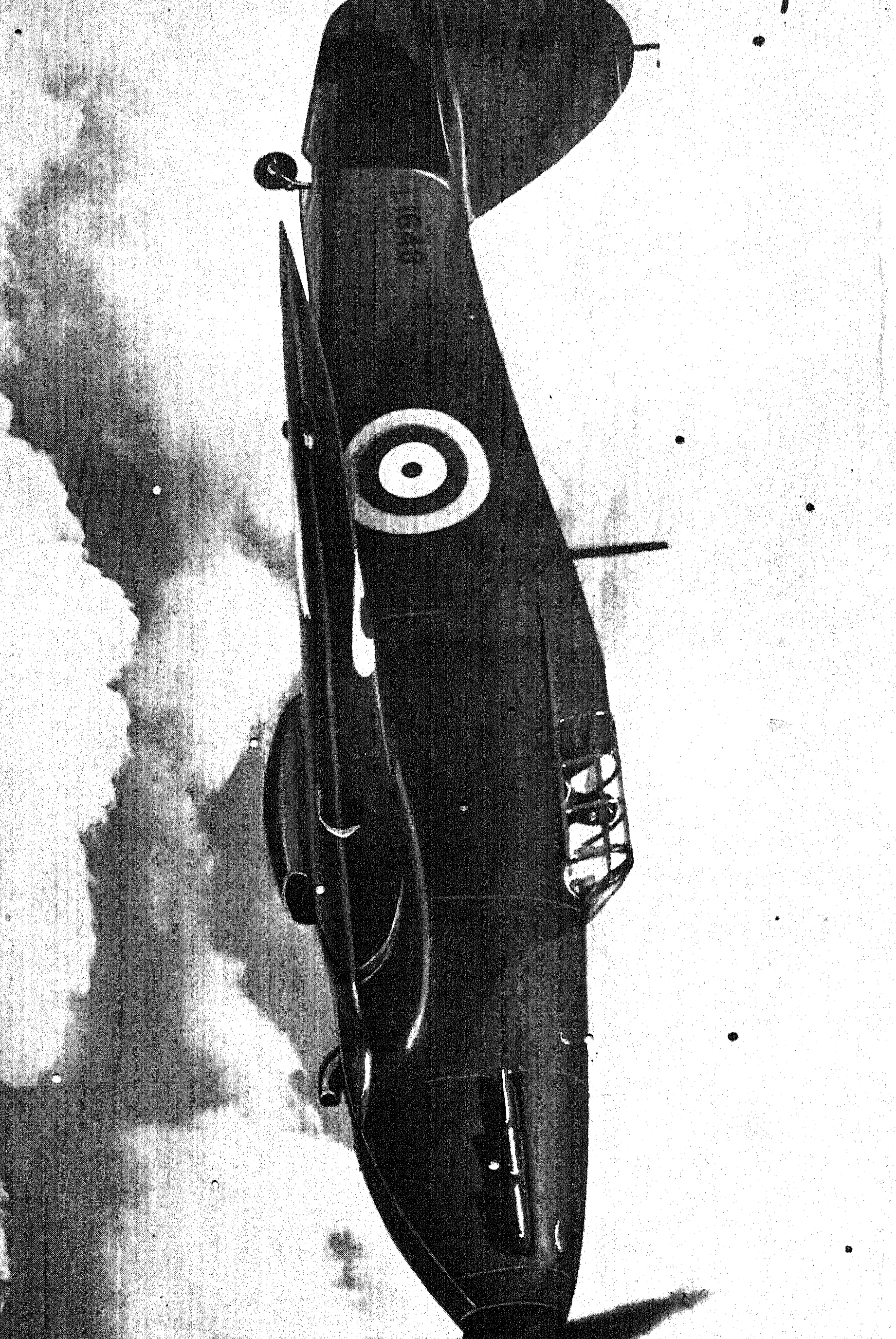

more likely to wear shields, sit on insulated mats and take other suitable precautions.

At the same time I should point out that ether vibrations of this type have been effective in dealing with small insects. Grain infected with small insect life can be cleared by running it in front of a miniature transmitter, specially designed for the purpose. The short waves literally shake the creatures to pieces and although they appear completely unchanged, in a few seconds they are lifeless. A suitably arranged transmitter can be made to act as a screen in front of open windows in summer. The ether vibrations will effectively keep out any insect, those that attempt to pass the invisible "curtain" falling dead. The effect may be that the body temperature is raised to the point where life is impossible.

To the layman it might seem a simple matter to produce the same effect on a larger scale and to use it against human beings. No doubt a man could be killed by having his temperature raised, but the range would be a few inches and the process would take at least a few minutes. It would be cheaper, more effective and more certain, to use a revolver. This really sums up the position regarding all the so-called death rays that have so far been demonstrated. One shown some years ago proved to be nothing but a concentrated heat ray. After being subjected to it for a considerable time, an unfortunate dog was killed; but it was no more than death by burning and the dog was very cruelly tied up to ensure that it did not walk out of range of the machine.

You will be safe in discounting stories you may read

or be told about death rays, and much the same applies to a number of weapons of to-morrow that are reported to have been invented. Discovery and invention are continuous. The invention of some of these rumoured marvels would be as surprising as if Columbus had managed to sail to America before Spain had discovered England. In other words they are illogically spaced in time, and we are led to inquire as to where the intervening research has been carried into practical effect.

Another suggested weapon of the future is that of infection by microbes. We are sometimes told that this might prove as effective a surprise in the next war as was gas in the last. I think it is just possible that attempts at the dropping of bacteria in bombs or shells will be made, although since it is obvious that the infection will remain and constitute a threat to the attackers, it may be that its use would be restricted. It is easier to use this weapon in theory than in fact. I understand that German technicians have made extensive studies of the possibilities of microbe warfare and that their report is not encouraging. The difficulties fall under a number of headings.

First of all we have the production of a sufficient quantity of whatever disease germs it may be decided to spread. It can be assumed that if the disease is to be introduced by bombing, by far the greater proportion of bombs will be ineffective so that huge quantities of active bacteria would be required. These could, of course, be prepared by laboratories normally engaged in the work of manufacturing serum; they would become the equivalent of the dye works in poison gas

manufacture during the Great War. But the culture of vast quantities of germs, artificially, might prove difficult. Our knowledge of bacteria is still very limited and it might prove that "inbreeding" might lead to the evolution of a comparatively non-virulent bacteria.

Next, there is the choice of a suitable disease. Many of the best from the point of view of the damage that would be done are passed on by mosquitoes or other parasites and not directly by the mouth or nose. For example, malaria, yellow fever and typhus. In many other diseases, from bubonic plague to spotted fever, animals or insects play an important part in distribution. I do not think it would be seriously contended that animals or insects ready charged with microbes could be dropped from bombs, although I was interested to read a paragraph not long ago which stated that Germany had prepared thousands of rats, ready to be innoculated with plague in the event of war, for sending across the frontiers. Actually, this is absurd, for the rats would travel, show no particular preference and would bite both sides with equal pleasure, spreading the disease indiscriminately. If it were possible to introduce a few thousand rats into the enemy's home-front there might be some point, but this is not so easy.

How are the diseases to be spread, if we rule out animals? Most bacteria are not very robust unless they are kept under suitable conditions. Bacteria of dysentry and other diseases soon lose their virulence unless kept in natural conditions. The infection of reservoirs with typhoid sounds simple, but typhoid

is easily destroyed and normal treatment of water in the waterworks involves the destruction of harmful bacteria including those of typhoid. Moreover, an epidemic could be quickly checked.

Three ways are suggested of spreading diseases. First there is the direct dropping of the cultures, either in bombs or by a spray. This would require ideal weather and one may assume that the vast majority of the germs would be so spread about by air currents that there would be few concentrations. Microbe "clouds" seem to have appealed to the German investigators as most hopeful, but they admit that the chances of their really spreading any infection are fairly remote.

The second method of spreading the disease is by animals, with which we have already dealt, and the third is by means of secret agents placing cultures in milk supplies or similar foods. Even assuming that a considerable number of spies could be concealed, able to receive cultures of live germs and spread them, the resulting epidemics would, in all probability, prove quite local.

Germany seems to have come to the conclusion that microbe warfare sounds better than it could prove in practice. But they point out the value of the weapon as a thread, the very possibility of it would keep an enemy country on tenterhooks. This, perhaps, is about the limit of usefulness of this weapon and, of course there is an old saying about crying wolf too often. The psychological effect depends upon the civilian population being of a fairly high standard of education, otherwise they would be unable to understand the danger. They would then

only have to know a little more to appreciate the difficulties and to take the risk at its real value.

Most of the other weapons that are described from time to time as having been invented, can be summed up as known weapons in a larger or more deadly form, and to a certain degree they have already been considered under their appropriate headings. It is sufficient here to say that the possibilities of a new high explosive, fifty times more violent than any yet known, are remote, unless we exclude explosives already known which are not used because their violence renders them uncontrollable and as dangerous to the users as to the enemy. Then there is the "super gas" a mere whiff of which sends a whole city to sleep. It exists in suitable form only in the imagination of writers of fiction. There are some 200,000 poisonous substances known, of which about 3,000 were seriously experimented with in the last war. Of these not more than a dozen proved themselves worth using in practice, and to-day, twenty years after the war, mustard gas or Lewisite probably remain the deadliest gases known. To suggest that some chemist experimenting in a secret laboratory might suddenly come across a new and more deadly gas is to misunderstand chemistry. Look at the formulæ of the various poison gases and you will see how closely they are chemically related in their various groups. You may take it that all possible compounds of the groups have been made and tested. There are many deadlier gases than those in use, but they are unsuitable for military use for the reasons which were explained under the heading of Chemical Warfare.

From time to time I read of new weapons which while I do not doubt they work perfectly well in theory seem to me to involve insuperable practical difficulties. I have mentioned some of these when dealing with torpedoes. Recently I heard of an ingenious "tracer" shell the light from which when it struck an aeroplane was reflected back, picked up by photo-electric cells in the shell which in turn were connected to the firing mechanism so that the shell was fired by any aeroplane near which it passed. This would solve all the difficulty of timing a fuse, but can anyone produce a photo-electric cell so rapid and robust that it will withstand being discharged from a gun? And do not forget that it is not well protected in the centre of the shell but is on the surface so that, presumably, it is the glass or other transparent material that would actually be nearest to the gun-barrel.

The rocket is another weapon that, it is often suggested, will revolutionize warfare in the near future. Most of the armies of the world have experimented with rocket artillery. It is true that a rocket might be built to travel a hundred miles or more, but at present its value is far from certain. First of all, the fuel for the rocket would occupy a great deal of the space which in a normal shell is given up to high explosive, and the cost of a rocket to carry a weight of explosives equivalent to a bomber might at least equal that of the aeroplane without any chance of the rocket being returned. On a smaller scale the anti-aircraft rocket may prove useful; rocket motors for aeroplanes are still outside the realms of practical design.

It has been suggested that with rockets it would be

possible to bombard London from the Continent, but anyone conversant with rockets would know that, even with accurate aiming, a miss by twenty miles would be quite possible due to air currents and other causes. As a terror weapon the long-distance rocket might be of some value, but for the effective bombardment of military objectives it would be useless certainly for many years to come. On the other hand, rockets for short-distance "bombing" have the advantage over artillery that they require only a light stand for firing instead of a heavy gun, so that the "battery" could be moved very rapidly from place to place.

Another suggested form of the death ray is "ultra-sound". Sound vibrations outside the limit of the human ear are known as ultra-sound and the vibrations go up to 300,000 per second compared with the 10,000 or so that represent the effective upper limit of the human ear. The physiological effects of some frequencies are powerful and it is possible that they might prove effective in incapacitating men, even if this was limited to nausea. The weapon would be all the more deadly in that it would be perfectly silent. But methods of producing high frequencies that will travel any reasonable distance have to be developed and the "beam" difficulty we find with wireless would arise. Moreover, unless the sound were restricted to a narrow path, it would affect the users as much or more than the enemy. Those experimenting with high frequencies have had to give up the work after a limited period owing to the physiological effects produced.

It is generally assumed that the next war on land will be mechanized and, as I have suggested when

dealing with tanks, this is a probability. But it must be remembered that the added complexity and the vast supplies of fuel necessary may have the same effect as the shortage of shells in the last war; the first fought with artillery as the major weapon.

I do not personally believe that any new war will "destroy civilization", although like all wars it will be economically disastrous alike for victors and vanquished. I do not think that the total casualties, if we suppose that both sides are well armed and defended, will be necessarily any higher than in previous conflicts; indeed, they may be far lower. Enormous strides in defensive measures have recently been made and the tendency is always towards stalemate so that war is not decided directly by battles but by morale, blockades and economic factors. The Great War, apart from the loss of life, cost, as far as can be estimated, ten thousand million pounds in Britain, that is, about ten times the amount of our present overswollen budgets. A low estimate for another war of the same duration with the present more expensive weapons would be one hundred thousand million pounds. Whether in fact this sum can be spent without reducing the population to a state of slavery I must leave to the economic experts, but I am inclined to the view that if science can make war expensive enough, it might reduce its duration by the financial exhaustion of combatant nations. It cost many thousands of pounds to kill a man in the last war, a point worth bearing in mind by those who place possessions before life or decency.

I might put forward the viewpoint that as everyone

is agreed that war must be a tremendously expensive affair, much more expensive even than the usual armed peace, it is a pity the nations cannot meet and decide from a purely economic point of view to divert these vast sums or energy into other directions. I do not think you will stop war by appealing to people's humanitarian instincts, because human beings are still savages and human optimism is such that it is always the "other fellow" who is going to get killed. But you can generally appeal to their pockets. What could we do with one-tenth the sum that would have to be spent on even a short war? Or perhaps one might ask, what couldn't we do? If a nation really wanted land, it could usually buy a far better tract for half the cost of a war and without the visitation of consequences upon many generations.

The United States paid nothing like the price of a war for Alaska. Colony-hungry countries could buy all the land they wanted for much less than the cost of a war which would reduce them to such a state that they would, in any case, be unable to develop the colonies they had won. For a hundred thousand million pounds you could almost take the Antarctic and make it a flourishing colony, more comfortable than any European country, with artificial sunlight generated by electricity produced by the never-ceasing wind. You could develop all the great areas of the world that are barren. You could give pensions for life to everyone in the country. You could endow medical research that would banish the fear of many dreadful diseases for ever. You could promote scientific research that would enable everyone to work only two or three hours

a day and yet enjoy an incomparably higher standard of living.

Few wars ever fought have "paid". Regarded as business propositions the wars of the past were the most foolish of investments. The Americans could have bought out all the slaves in the Southern States for about forty pounds a head or a total of two hundred million pounds. Instead they decided to settle the issue by war and, apart from the enormous loss of life or the unhappiness caused, spent over one thousand million pounds. America, incidentally, is in a better position than a small country spread into departments all over the world and costing so much to maintain that possessions could be a serious liability, like a business which opens branch establishments without sufficient staff or money to ensure their economic success. War should be worthwhile from the prosperity point of view as well as that of intangible prestige.

Have you ever been disgusted when reading of a family, left a very large fortune, quarrelling over the division of the spoils? That is the sense I have of war. Here is the earth, marvellously left to us with more raw materials than we can ever consume. Here are we with brains painfully evolved at the sacrifice of millions of lives and countless generations of animals, brains with enormous potentialities. And the only way we can think of deciding arguments is by fighting; we dissipate all the wealth or comfort that has been won for us by scientific research, like savages at their dirtiest and worst.

But it is as well that there should be no misunder-

standing in regard to the future of War. There is no such thing as a "war to end war", peace does not exist upon the only earth we know, nor do we encourage any other condition than that of the bitterest conflict. Industrial composition is based upon a system of evolution to which all nature subscribes. The desire for individual power cannot be taken from mankind without, at the same time, removing the urge of progress. Money is of no value unless there are others who have less money, land is uninteresting unless it is land that others desire. Useless to buy land when it can be obtained by fighting, so long as each individual believes that he can, personally, benefit.

So war will continue, and if we plot curves to show the number of occasions when war has acted as a spur to research, we are left with overwhelming proof that upon every occasion there will be a ruthless search for the most terrible weapons that human beings can conceive. I shall expect the attack upon so-called civilians to be of particular violence. It is useful to kill women and children when terror is a main objective. I believe that, if enough progress in the art has been made, television and radio will be used to bring the sights and sounds of war into our homes. If it is possible to prepare for war by sterilizing a male population twenty years before hostilities it will surely be done. I shall expect attacks by silent aeroplanes, the use of machines which burrow into our shores from the sea, travelling or delay action bombs, and the eventual success of electric weapons which can blind, torture, kill or maim thousands at the touch of a button.

It horrifies me to describe an unending array of weapons, to disclose an ever-increasing ingenuity of purpose which seems almost entirely evil. For future wars will respect no life; I shall expect to see the satisfaction with which women are drawn into the theme of slaughter under the guise of patriotic endeavour. It gives me little pleasure to realize that, within a few years, we shall produce aeroplanes so fast that a few days' journey will encircle the world when I know the end to which such discovery will be put.

It seems a poor aim for scientific achievement that pilotless planes can be watched by television as they turn human beings into mangled flesh. And I am very sure that invention has not yet finished with war. There is no form of technical knowledge or skill which has not been called upon to do its worst. Gases to poison pilots in the air, bombs which follow aeroplanes, or searchlights; tanks that travel at 60 miles an hour, portable trench mortars, guns which can penetrate many inches of armour, all are hailed with delight as a proof of the skill with which we conscript men and machinery in the defence of possession. Nations are proud of the fighting instincts of their children; I doubt if the much-vaunted movement towards health would have succeeded in times of peace.

Unless it is feasible to achieve some form of equality between nations, people, and thought; unless world-wide communications and intermarriage can provide some common enemy to conquer, we may rest assured that peace is unattainable without armaments until

every living soul is of one colour or one mind. I believe, in short, that the future of war, armaments and human nature are utterly inseparable. It has never yet been proved that peace and progress are equally combined.

CHAPTER XVII

SWORDS INTO PLOUGHSHARES

WAR IS INTENDED to be entirely destructive in its ends. The test of an effective weapon is the amount of destruction, direct or indirect, that it is capable of causing. To the scientist, war should have absolutely nothing to recommend it, for the purpose of science is to create and not to destroy. But it happens that the results of war are not all evil. These beneficial results could be obtained infinitely more cheaply in other ways; but so long as wars continue to be fought, we must be content to accept the benefits that come of them and to admit that, in the present state of human development, there are very many valuable technical developments which would never have taken place but for the everlasting fighting of mankind.

Generally speaking, the benefits of war are the result of the fact that when a nation is defending its existence it throws into the struggle all the reserves of money and man-power it possesses. It is true that we ought to be prepared to show the same enthusiasm for the abolition of disease, poverty, or even road accidents; but, for various psychological reasons of greed, we are often as indifferent to suffering as we are

enthusiastic for its cause. The result of this wholeheartedness for war, the one cause, apparently, that can unite a nation, is that technical development and invention are tremendously stimulated. The moment war breaks out, money becomes no object. Any scientist or inventor with some method of destroying more people or things is certain of a hearing and probably of support. The British Government paid out some millions of pounds for inventions made during the Great War. It has paid out nothing like this sum for inventions in time of peace. Self-preservation remains a prime instinct and under its urge more progress is made with the development of inventions in a year of war than in twenty years of peace. Can anyone suggest that £700,000,000 would ever be raised for the rebuilding of Great Britain or the rehabitation of her industrial needs?

Consider the development of flying during the Great War. At the end of two years greater progress had been made than in the previous ten years. Aeroplanes entered the war, flimsy affairs of bamboo and canvas, unable to fly in any strong wind, with a very short range and equipped with only the most primitive instruments. But when the lives of nations began to depend upon the technical efficiency of their aeroplanes, the slow and painful development of the aeroplane gave place to rapid improvements, one type replacing another at a speed impossible under normal peace-time conditions. The aeroplane emerged from the war a powerful machine, capable of carrying a load measured in tons and of flying more than a thousand miles without refuelling.

Just before the war prizes of thousands of pounds were being offered for first flights across the Channel or round Britain. The idea of a flight across the Atlantic seemed almost infinitely remote. But in just four years cross-Channel flights became an everyday affair and a flight across the Atlantic a real possibility. It was, in fact, an adapted army bomber which made the first non-stop crossing of the Atlantic; the pioneer flight in the establishment of the regular trans-Atlantic mail service just achieved. Great as has been the improvement in aeroplanes in the twenty-one years since the war, it has not been so comparatively marked, as it was in the four years of actual strife. Even the pleasure motor-car benefited by the discovery of many new alloys.

Swords are still beaten into ploughshares at the end of a war, in the figurative sense, and the tendency for this to happen becomes greater as war becomes a more and more technical business, utilizing every resource of industry. In the case of aeroplanes, the change from military to civilian uses was comparatively simple. Mail bags were substituted for bombs. The strength required of military aeroplanes for manœuvring provided a reserve for the reliability required for civilian aeroplanes.

Wireless developed rapidly in much the same way. The necessity for making apparatus portable had an important effect which was to be of great value in the earliest days of broadcasting. Wireless telephony was in its infancy in 1914. Conversations between vessels some forty or fifty miles apart were considered an achievement. During the war there was continuous

development of the thermionic valve which was to make broadcasting possible. The great advantages of having aeroplanes in communication with the ground stimulated experiments in this direction, most valuable after the war in providing a means for controlling and safeguarding civil aircraft. Very great progress was made with directional wireless, because this enabled the position of enemy vessels to be determined. The principle of finding a position by wireless is fairly simple: the direction from which signals are coming is determined from two different positions, when a simple trigonometrical calculation gives the bearing. This and beam stations are the standard methods by which aeroplanes determine their position in flight to-day, although the reason for the shore stations established for this purpose has changed from one of destruction into one of safety. The direction-finding stations erected by the Government during the War were afterwards made available for the Merchant Service.

If we take another weapon, the tank, we see that this also benefited the world when it returned to peace. The great experience gained of the methods of utilizing caterpillar traction provided a variety of purely commercial vehicles designed for working in rough country approximating to that of the front lines. Tractors for farms became more efficient, road-making machinery was developed which was based on experience gained in devising machines for working on broken land.

The War gave great stimulus to the chemical industry, not only in the production of explosives, but in the manufacture of fine chemicals. Britain depended upon

Germany for a number of products and suddenly found her source of supply ended. The result was that chemists were told they must make the required materials at any price. Certain branches of research received help in this way and progress was made very much faster than would have been the case under circumstances of commercial competition.

The fact is that in these days war is no longer fought by detached armies, drawing their equipment and weapons from factories solely engaged in their manufacture. There is no factory that cannot rapidly turn from the manufacture of peace-time articles to the manufacture of those useful in war, no chemist whose research cannot branch off into something that might be useful for war, no invention that cannot be adapted for fighting. The opposite is also true. Although war is wholly destructive, it is now so closely linked with civilian life that the change over is often a matter of mere adaptation.

Take the case of the weapon considered the basis of modern war, explosives. The explosive that can be employed to cut enemy wire and destroy his fortifications can also be used to blast through rock to provide a tunnel for better communications, to secure raw materials from the earth, or to knock down old houses before re-building. In actual fact the amount of explosive produced for purely commercial purposes far exceeds that produced for war. Without the thousands of "shots" fired in coal mines, it would be impossible to produce all the coal that is required to-day. Every "shot" replaces hours of laborious work. The hundreds of thousands of tons of explosive used

for breaking loose rock represent some millions of hours of work by miners with pick and shovel.

Experience gained in the safe-handling of explosives in war-time later becomes valuable for commercial purposes. The object of an explosive is to shatter, but not until the desired place is reached. This applies equally to mining as to war and the practice gained in making and firing explosives for shells is utilized in felling a chimney by explosives or to tunnel out rock under a city. Some of the farmers who saw shells making holes where they exploded may, perhaps, have thought: "What a pity I can't have a shell to dig holes for my trees when I plant them—it would take a couple of men all day to make a hole like that." This use of explosives is now a fact. A small charge of explosive not only produces the required hole, but breaks up the ground underneath so as to make the work of the roots of the newly-planted tree easier. Telephone poles are erected by holding them over a buried charge which, when it is exploded, lets the pole drop neatly into position.

We owe a great debt to the development of explosives for warlike purposes. Compare a tunnel cut with the aid of explosive in San Francisco recently, with the cutting of the ancient Mount Salviano tunnel for the Emperor Claudius. Explosive cut the tunnel through the rock at the rate of 750 feet a month. The 30,000 slaves used by the Roman Emperor in pre-explosive days cut only 5 feet of rock per month for eleven years.

Explosives have been used to destroy icebergs when they were menacing shipping routes and bombs have been used to divert floods, both of water or of lava from

volcanoes. The explosives used for peaceful purposes are, for the most part, different, for technical reasons, from those used to fire shells or fill bombs. But explosives are now a peace-time necessity no less than the basis of modern war and it is most doubtful if they would have been developed to their present stage but for the stimulation of war.

Another agent of destruction for which we have to thank the Great War, was poison gas. It would seem that nothing good could come from this weapon and no use found for it when the time came to turn to peace. But most of the war gases have been harnessed for peace-time use. For many years hydrocyanic acid gas was used for fumigating ships to rid them of vermin and rats. The gas is effective, but it has the disadvantage of being colourless and odourless so that even with the greatest precautions accidents happen in which it is breathed by human beings with fatal effect. As a result of war-time research with poison gases, hydrocyanic acid gas is now mixed with cyanogen chloride or some other tear gas which is persistent and so gives instant warning of its presence. Thus a gas primarily designed to destroy life has achieved a humanitarian purpose.

Other poison gases such as chloroarsenic gas have been successfully used for killing plant pests or treating animals for vermin. The prickly pear cactus is one of the plants that is most difficult to destroy, cutting being not only laborious but almost useless. Now a method has been developed of gassing which is safe and effective. The gas is injected into the plant through a hollow needle from a small generator which

is easily carried round by the farmer. This kills the plant in about three days, and moreover kills it completely so that it cannot grow again as it does so often after ordinary methods of destruction.

Some poison gases have been found useful for many other purposes. For instance, chloroarsenical gases have been introduced into wells to give the water medicinal qualities. For this purpose cartridges containing chemicals which combine to produce the gas have been dropped into wells and exploded. The same type of apparatus has been used for destroying insect larvæ in swamps, the cartridges being dropped into the water and the chemicals allowed to spread through its mass. Poison gases have also been used for destroying rabbits or similar animals when they have bred in dangerous numbers, the gas proving a humane and simple method of getting at them in their burrows.

The "ideal" method of distributing mustard gas, which is not a gas at all but a volatile liquid, is by spraying from the air and considerable research by military authorities has been carried out with this object in view. The first experiments showed that liquid sprayed from an aeroplane, owing to the speed at which it was moving through the air, was formed into such small particles that it remained suspended instead of falling like a gentle rain. To overcome this difficulty devices were invented for shooting the liquid backwards so that the air pressure in front was neutralized. The spray then fell to the earth in a fine mist. In ideal circumstances this would, of course, be a deadly method of attacking troops or civilians. But even this "evil" has proved useful. The secret of spraying

liquids from aeroplanes has been utilized for treating orchards for pests and for distributing fertilizer and seeds on large tracts of land. Aeroplanes have been extensively used for spraying poison over cotton fields attacked by the boll weevil, the great advantages over spraying from the ground being not only more effective coverage but a great saving in time.

The scientist's reply to poison gas in the War was the invention of the gas mask. This is not less usefully employed in peace-time for minimizing the effects of poison gas accidentally encountered in mines or in certain manufacturing plants. Many scores of different kinds of gas mask are now used in industry from the simple breathing-pad which gives protection against the absorption of minute mineral particles likely to damage the lungs, to masks specially designed to give protection against ammonia encountered in refrigerator accidents, and independent breathing units used for mine rescue work or similar occasions. The independent units owe much of their efficiency to research carried out to provide military airmen with oxygen when flying above a height of 30,000 feet. Research in masks has led to the development of elaborate affairs equipped with telephones and eye-pieces enabling optical instruments to be used while worn.

One other use of poison gas must be mentioned, that of humanely subduing crowds or criminals. It may seem that tear gas is not very humane when used on crowds, but it is certainly better than the alternative of firing into the mass of people to cause certain death or injury. Certain tear gases do no permanent damage, but cause temporary blinding and sneezing so that action

is impossible. There is also a psychological effect of helplessness which can best be summed up by saying that the victim wants above all things to go home. The effect is quite temporary, but the curious thing is that although a man may have considerable experience of tear gas and know that he will be all right in a short time, the effect is still the same after many experiences.

An armed and desperate criminal has not infrequently killed several policemen who were trying to take him alive, before he will surrender. Tear gas bombs provide a simple remedy without permanent harm or loss of life. It is doubtful whether the British will ever permit the use of tear gas for the dispersal of crowds or even for the arrest of criminals, but this is largely due to false sentiment. If crowds must be dispersed, there is no doubt that a suitable gas provides by far the most humane method. Baton charges, however carefully made, are bound to result in injuries or even in deaths. With tear gas there is no stampede in which people may be accidentally injured.

Other weapons of chemical warfare have also been adapted for peace-time uses. Flame-throwers, one of the most unpleasant weapons of the War, were introduced in New Zealand to attack the blackberry or gorse which have become a considerable pest and are "stealing" rich land. The flame-thrower has, of course, been specially adapted for agricultural needs; it burns crude oil, throwing a flame several yards ahead and destroying not only surface vegetation but also roots. Incidentally, it is interesting to note that the protective asbestos clothing used for the men who had to handle flame-throwers has been developed and is now extensively

used in many industries where there is danger of clothing becoming fired. Experiments have also been conducted with flame-throwers in England for destroying blight on potato crops. In a wet season, it is impossible to spray the crops and the blight gradually reaches the root. A small flame-thrower destroys the foliage but leaves the tubers unharmed.

Thermit which, as has been explained is now the usual material used in incendiary bombs, is far more useful in peace-time for welding. The intense heat generated makes it possible to melt the metal for the two parts that are to be joined so that they flow together. It is particularly suitable for welding large pieces that cannot be effectively treated by electricity or the oxy-acetylene flame, and huge charges of thermit, up to 4,000 lbs. have been used for big welds. It has the advantage that the formula can be varied in accordance with the nature of the iron or steel to be treated. For instance, thermit used for welding railway lines has in it small percentages of nickel and manganese, while thermit used for welding cast iron is incorporated with a small percentage of ferosilicon.

There are many interesting examples of chemical adaptations. For example, the fact that titanium compounds were excellent for smoke screens, because the particles were so very finely divided, led to an investigation of the possibility of their being used for paints and dyes. Titanium compounds are now used as "fillers" for very thin paper to secure opaqueness, and as a dye for rubber compounds. Normal dyes are unsuitable because either they do not stretch and so they reduce the elasticity or they fail to give uniform colour.

The minute particles of titanium make it almost ideal for this purpose.

War provides stimulation in some little-expected quarters. Methods of surgery developed very fast, for while much was necessarily performed under primitive conditions, surgeons obtained more experience of certain types of operation in a few months than they were likely to get in years of peace. The experience gained in the treatment of fractures has undoubtedly benefited thousands, and a comparatively new branch of the art, plastic surgery, reached a high state of development. Plastic surgery is largely devoted to the repair of ugly scars and disfigurements, particularly on the face or hands. The technique used in the War has unfortunately only too often proved useful latterly in the repair of disfigurements due to road accidents. X-ray work also received an immense stimulus during the last war.

Another instance of rapid progress made due to war is that of aerial photography. Photographs were wanted during the War to show up gun emplacements, ammunition dumps and troops. Ordinary methods of map-making were, of course, quite impossible when dealing with enemy territory. The first photographs only showed a certain area which had to be afterwards identified and fitted into the general map by the noting of landmarks. But as time went on special aerial cameras were developed which at the moment of exposure also recorded the time, height and other vital information. With the coming of peace, these cameras were adapted for surveying and have proved exceedingly valuable. Not only have they made possible the mapping of un-

developed areas, such as jungles and trackless swamps, but they have also brought about the rapid revision of maps made by ordinary methods of surveying. Building development, particularly in the neighbourhood of large towns has often been so rapid that the usual methods of map-making were useless, the maps being out-of-date by the time they were completed. Aerial photography enables maps to be quickly and constantly revised, an aeroplane covering in a few hours an area which would take months to survey from the ground.

In these days of "total warfare", food supply is of great importance, particularly to a country which is dependent upon imports. Food shortage resulted in research which has been equally valuable in peace-time. The lack of certain vital food elements led to the first real research into the requirements of the human body for health and to investigation of the problem of national nutrition. The storage of food, first organized with a view to times of war, is of equal importance as a protection against famine due to the failure of crops, and to the even distribution of food over the year so that glut or shortage do not alternate. It is interesting to recall that canning really owes its origin to Napoleon who, anxious to discover some method of preserving food for his armies, offered a large prize for a suitable method. The idea developed by Appert, the winner, was not strictly canning, but preservation by heat and the exclusion of air. It laid the basis of this vast industry and tinned food has, since then, always been a vital part of soldiers' rations. The constant demand for this particular purpose has stimulated research and

gradually led to the present very high standards of canned foods.

The use of aeroplanes to carry men or materials over the enemy lines so that they may be dropped to advantage has already been described. This has been adopted for peaceful purposes. Both France and Russia have developed from the military manœuvre a service by which doctors or nurses can be dropped by a parachute at lonely spots where it would be impracticable for an aeroplane to land. In Moscow there is a permanent medical "flying squad" which has been used on many occasions to take medical aid to remote villages. Russia has also used the parachute for sending firemen and fire-fighting apparatus to forest fires in lonely districts where no suitable landing field is available. Parachutes from aeroplanes have been employed, not only for dropping food and fuel to advance troops, but also for sending supplies to men marooned by floods in the United States or when cut off on islands.

Experiments carried out by the R.A.F. have resulted in the production of a special container so effective that several dozen eggs have been dropped from a considerable height without breaking. This opens up great possibilities for the sending of mail and freight by non-stop aeroplanes. The invention of the arm that catches mail-bags at lonely stations without necessitating an express train stopping, saved the railways hundreds of minutes a day. The use of the mail parachute may result in a great saving of time for air-mail delivery to towns without a suitable landing field.

An interesting example of the value of supplies dropped by parachute was afforded in a lonely part of

Rhodesia not long ago. There was an outbreak of foot-and-mouth disease. To bring the requisite medical supplies by native runner would have taken many days. There was no suitable landing ground for an aeroplane. The supplies were packed and attached to parachutes, which were dropped over the village. The reduction in time thus effected resulted in many hundreds of cattle being saved.

It may be poor consolation, but nevertheless, it is something to know that almost every development of war has its peace-time use. The machines that dig trenches for men to hide from bullets can also cultivate land or dig trenches to take water pipes. Research designed to produce better steels for armour or shells, or stronger alloys for aeroplanes, can make our peace-time motor-cars, bridges or aeroplanes stronger and safer. Perhaps it is not quite impossible that all this could be done without killing millions of men and destroying whole towns. Perhaps one day we will decide to devote one-tenth the sum given to war for the stimulation of research that will add to the hope and even the happiness of our fellow creatures.

CONCLUSION

THERE IS NO CONCLUSION to war. There is no end to the weapons that may be invented for its prosecution. If I plot a curve showing the list of wars and the number of people killed, blinded and mained with the passing of time, it will be found that this line of which history forms the base, is steadily rising as the world becomes more populous.

I very much doubt if it would be possible to find anything in nature that does not fight. It has been suggested that crystals engage in some everlasting dance of death of which so simple a thing as rust is one example. I know that if I take a cinematographic picture of a forest at the speed of plant life and turn my projector faster in order that it may compare with the rate of my own living, I shall see shrubs and creepers tearing trees to pieces just as throughout the animal kingdom one does not breathe without taking life.

It is not for me to suggest whether this is good or bad. This is arguable; because all of us enjoy such pleasures as motoring and radio. We appreciate flying, the blessing of X-rays, plastic surgery, synthetic cloth and margarine. But I find that these important inventions were developed as the result of war, and that they came to a practical state far more quickly

than would have been the case, in times of peace when even a few thousand pounds for the maintenance of a road is difficult to discover. The same road can be torn up, repaired, altered and covered with factories in a few months if guns or poisons are needed to defend our possessions.

I also know that if I keep chickens in a small garden, without making them scratch for their food all day, they will soon develop a peculiar species of corn which will introduce degeneration very quickly. It seems to me that competitive examinations, competitive industry and international finance are all a form of warfare. There are occasions when a declaration of peace might be a financial calamity; to some people is it not rather like a chemical experiment in which heat may be produced slowly over a long period of time, or when the same heat is given off very quickly, and we term the result an explosion rather than gradual combustion?

If the war of peace is strenuous, open conflict is at least more intriguing in its scientific methods, so I am convinced that we should look upon our modern weapons in exactly the same way as we regard a bow and arrow. We realized that the arrow must go further and faster so gunpowder was invented. We must now say that it is not enough to detect the movement of aeroplanes by heat, radio waves, or sound. We must be able to put up some electrical barrage. We must counteract the fact that the speed of aeroplanes might eventually exceed that of sound, we must allow for the obvious truth that important buildings should be built downwards, not upwards, and we must cope with the thought that a sloping seashore presents an oppor-

tunity for submarine tanks to glide unexpectedly on to our land.

There are many other ideas which may sound bestial but which are no worse, in my opinion, than the molten lead of the past. I have never seen the mercy of being shot by a 2-inch gun when a 3-inch is claimed as illegal by a law or commercial agreement which can only be maintained by the agency of the very weapons which the rule attempts to prohibit. So why not begin early? In wars of the future it will be possible, perhaps, to prepare one generation ahead, not by Cadet Corps or Conscription, but by some form of sterilization so that the proportion of scrofulous males will be increased, so that rickets will be prevalent, and, by electrical means, so that unsatisfactory children from the aspect of war are invariably born. Women, of course, will fight too because there will not be enough to man the weapons of science without their aid. The history of world wars shows very little peace in the interim, and wars nowadays do not end, they are merely adjourned for a few years so that each side can begin a more intensive propaganda and by invention or research can bring force to their side.

Intensive propaganda we have not yet experienced. When we can look in and listen in to war it might make us wonder. When photographs are published of weapons they should, I think, always be accompanied, as an inset, by the result they produce; for I am more than certain that the lust of conquest and of armament invention are too human to cease in this world. I believe, quite seriously, that within the next few thousand years it might be possible to reach such

heavenly bodies as the Moon. It will be found, by the simple process of producing the curve of history into tendencies of the future, that interplanetary exploration parties from other spheres, equipped with bacteriological or electrical death, will whip up the indignation of the world in exactly the same way as now applies to small continents. This may be a good method of securing a reasonable peace; to explain that some universal danger is threatening the whole earth. In a few days we should be hearing that our late enemies were those plucky souls who put up a spirited resistance in some corner of the globe which has only just begun to appreciate the value of civilization. Necessity can make the strangest bed-fellows in a noble cause.

Hartland, 1939.